

# KRISHNA KANTA HANDIQUI STATE OPEN UNIVERSITY

**PROGRAMME PROJECT REPORT**  
ON

**MASTER OF SCIENCE**  
**(MATHEMATICS)**



Submitted to  
**UNIVERSITY GRANTS COMMISSION**  
**NEW DELHI**

Submitted by  
**K. K. HANDIQUI STATE OPEN UNIVERSITY**  
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## 1. OVERVIEW

Master of Science (Mathematics) is a postgraduate programme offered by Krishna Kanta Handiqui State Open University (KKHSOU). The programme is designed to promote the scientific temperament of the learners in higher education by providing easy access to all those learners to improve their qualification, skills and competence. The duration of the Master of Science (Mathematics) is two years, and the curriculum is divided into four semesters. The Master of Science (Mathematics) is structured with core courses specific to the discipline (DSC) and a selection of elective courses (DSE) to provide students with a comprehensive understanding of the field and diverse learning opportunities. Additionally, ability enhancement courses (AEC) and value-added courses (VAC) are bundled and offered to students. Since the university organizes its academic disciplines into a school system, it is anticipated that multidisciplinary and interdisciplinary courses for AEC and VAC will be seamlessly implemented with related faculty members available to teach them. Furthermore, the university is registered with the Academic Bank of Credit (ABC) to allow students to transfer credits easily and provide them with greater flexibility in selecting courses. The Centre for Internal Quality Assurance (CIQA) at the University has organized several meetings and workshops to design programmes in the context of ODL. With the inputs gathered, the Committee on Courses (CCS), along with outside subject experts from reputed Universities of the region, have designed the Programme and detailed syllabi. The updated and revised syllabus was then presented to the Schools of Studies, and after receiving due recommendations, it was approved during the 38<sup>th</sup> Meeting of the Academic Council on 6<sup>th</sup> December, 2023. This Programme Project Report (PPR) outlines the Two-Year PG Programme on Master of Science (Mathematics) in under the Discipline of Mathematics at the Hiranya Chandra Bhuyan School of Science and Technology of KKHSOU, which is the outcome of this process.

## 2. PROGRAMME MISSION AND OBJECTIVES

### 2.1 Mission and Vision of K. K. Handiqui State Open University:

- i. The motto of the university is to make education beyond barriers and provide the educational opportunity to the unreached irrespective of gender, socio-economic status, geographical location, physical disabilities and gender.
- ii. It will also provide education to the housewives, semi-literate, unemployed youth, jail inmates as well as highly educated people.
- iii. This university provides the opportunities of higher education to those who remain deprived of higher education for other numerous reasons.
- iv. The mission and vision of the university is to enhance the capabilities of learners, particularly women learners, who want to get

empowered with higher order of required education and necessary professional skills.

- v. To provide social justice to all the stakeholders is the prime focus of the university.

## **2.2 Mission and Objectives of the Programme:**

The mission of the Master of Science (Mathematics) programme is to provide systematic and complete knowledge of Mathematics so that learners can develop the ability of logical thinking, computational skill and research skill.

The objectives of Master of Science (Mathematics) include the following:

- Nurturing a mathematical mindset and fostering learners' interest in problem-solving skills.
- Cultivating computational prowess and honing programming aptitude.
- Enriching learners' understanding and proficiency in mathematics and its allied domains.
- Fostering a deeper comprehension of mathematical concepts and their diverse applications.
- Empowering learners to apply their knowledge in tackling complex scientific challenges and achieving global professional competence.
- Imparting knowledge on advanced concepts and practical applications across various domains of Mathematics.

## **3.RELEVANCE OF THE PROGRAMME WITH KKH SOU'S MISSION AND GOALS**

- i. The programme provides learning throughout life by giving learners an opportunity in the entry and exit point of learning without any age bar. This also signifies equity and access in the field of higher education.
- ii. The programme is crafted to cultivate proficiency in mathematical modeling, programming, and computational techniques essential for employment in both academic and industrial settings. During syllabus design, the consideration was given to the possibility that learners might originate from

disadvantaged academic backgrounds or remote geographical areas. A primary goal of this university is to deliver high-quality education to individuals in geographically isolated regions. Consequently, it is anticipated that this programme will contribute significantly to the university's pursuit of its objectives.

#### **4. NATURE OF PROSPECTIVE TARGET GROUP LEARNERS**

The target group for this programme includes:

- a) Graduates with mathematics as one of their subjects at the undergraduate level, teachers from various schools seeking further education, and individuals from different corporate backgrounds who wish to pursue higher education after being unable to complete their previous studies.
- b) The Master of Science (Mathematics) is tailored to cater to the diverse needs of individuals interested in pursuing careers or advancing their education in the field of Mathematics.
- c) The target learners include students who have been unable to secure admission through conventional system due to dropout situations primarily stemming from social, financial, and demographic factors, as well as individuals of any age residing in remote areas where access to higher education institutions is limited.
- d) The Master of Science (Mathematics) is designed for those who have completed an undergraduate degree programme in Mathematics from a recognized university, as well as graduate teachers (assistant teachers) as the primary target audience.
- e) It also aims to serve the rural population, enabling them to fulfill their aspirations for higher education, which may have been hindered by the limited availability of seats within the traditional university system.

It is anticipated that one thousand learners will enroll in the Master of Science (Mathematics) programme, encompassing all potential target groups.

## **5. APPROPRIATENESS OF THE PROGRAMME TO BE CONDUCTED IN ODL MODE TO ACQUIRE SPECIFIC SKILL AND COMPETENCE**

Master of Science (Mathematics) programmes can be appropriate to be conducted in Open and Distance Learning (ODL) mode, depending on the specific skills and competencies that the programme aims to develop, the quality of the ODL delivery mode, and the level of support provided to learners.

Here are some of the factors that can make Master of Science (Mathematics) is suitable for ODL delivery mode:

- a) Flexibility: ODL mode allows learners to study at their own pace and schedule. This flexibility can be especially beneficial for working professionals who need to balance their studies with their work and personal life.
- b) Accessibility: ODL mode enables learners to access educational resources and instruction from anywhere in the world, as long as they have an internet connection. This can increase the accessibility of the programme to learners who may not have the opportunity to attend a traditional, on-campus programme.
- c) Cost-effectiveness: ODL mode can be more cost-effective than traditional, on-campus programmes, as learners do not have to incur expenses related to travel, accommodation, and other on-campus expenses.
- d) Personalization: ODL mode allows learners to customize their learning experience to suit their needs, preferences, and learning styles. Learners can choose the specific courses or modules that align with their career goals and interests.

Overall, Master of Science (Mathematics) can be appropriate for ODL delivery mode if the programme is well-designed and delivered, and if learners are provided with the necessary support to succeed in an ODL environment.

## 6. INSTRUCTIONALDESIGN

### 6.1 Curriculum design:

The Master of Science (Mathematics) has been so designed that it meets the standards of the UGCODL Regulations 2020. With the help of experts in the subject from other reputed Universities in the region, the contents of the syllabus are updated.

### 6.2 Programme Structure and Duration of the Programme:

The minimum duration of the Master of Science (Mathematics) is 2 Years (4 Semesters). A detailed outline of the programme can be found in *Annexure I*. The detailed course wise syllabus of the Master of Science (Mathematics) is given in *Annexure II*.

### 6.3 Credit Hours:

As per UGC ODL Regulations 2020, the University follows the system of assigning 30 hours of study per credit of a course. Thus, following this norm, a 4-credit course constitutes a total of 120 hours of study. Out of the total credit hours, a minimum of 10 percent, i.e., minimum 12 hours of counselling per course are offered to learners at their respective study centres both face to face and online mode.

### 6.4 Duration of the programme:

The minimum duration for completion of Master of Science (Mathematics) is two years and the maximum is double the minimum duration i.e., four years as per the new regulation 13(A) 2 of UGC.

### 6.5 Faculty and Support Staff Requirement

The Discipline of Mathematics of Hiranya Chandra Bhuyan School of Science and Technology of the University currently has three full time faculty members. As the Master of Science (Mathematics) has components of Ability Enhancement Courses (AEC) and Value Addition Courses (VAC), it requires interdisciplinary and multidisciplinary effort. Therefore, support of faculties from different schools of the University has been mobilized for design and delivery of the Master of Science (Mathematics). A list of course coordinators against each core courses of this Master of Science (Mathematics) is presented in *Annexure V*.

The Discipline of Mathematics under the Hiranya Chandra Bhuyan School of Science and Technology of the University has the following teaching staffs:

Sl. No.	Name	Designation	Qualification
1	Mr. Harekrishna Deka	Assistant Professor	M.Sc, SLET Qualified



2	Mr.Kumar Napolean Deka	Assistant Professor	M.Sc., NET JRF Qualified
3	Mr. Rupam Shankar Nath	Assistant Professor	M.Sc., NET JRF Qualified

## 6.6 Instructional Delivery Mechanism

The Self Learning Materials have been prepared keeping in mind the requirements of instructional design. Particular attention has been given so that the basic three domains of knowledge, viz., the behavioural domain, cognitive domain, and constructive domain can be addressed. In general, the university offers printed SLMs and the same in audio-visual formats. Apart from that, plans are being made to deliver the Master of Science (Mathematics) through LMS. The LMS would consist of four quadrants: video lectures, downloadable/printable reading material, self-assessment tests through tests and quizzes, and an online discussion forum for clarifying questions. As majority of the learners are from rural areas and disadvantaged groups, attempts are made to make the SLMs easy to read and easy to understand with the following major components:

- a) *Learning Objectives* (major objectives of the Unit are stated)
- b) *Introduction* (linkage with previous Unit as may be applicable and general introduction of the content is provided)
- c) *Check Your Progress* (generally after every section CYP is provided to learners to gauge their understanding)
- d) *Answers to Check Your Progress* (CYP answers are provided at the end of the Unit)
- e) *Activity/Activities* (activities for enhancing learners' critical outlook is included in SLM)
- f) *Let us Know* (Depending on the necessity some important information related to the content is provided in a box)
- g) *Let Us Sum Up* (pin pointed summary of the Unit is given)
- h) *Further Reading* (this section has been incorporated for those learners who are interested in advance knowledge of the content)
- i) *Model Questions* (Different types of questions have been provided in the unit).

## 6.7 Identification of Media–print, Audio or Video, Online, Computer Aided

All learners are provided with Self Learning Materials, which are comprehensive in terms of the contents of the syllabus. These learning resources are prepared with the help of resource persons across the state/country. Senior/Retired Professors/Associate Professors/Assistant Professors from different Universities/Colleges are engaged as SLM writers and Content Editors.

## 6.8 Learner Support Services

The student support services available in the University would be extended to the learners of this *Model Questions* (Different types of questions have been provided in the unit). Programme. All these support services would help the learners to imbibe the

required knowledge and skills; to seek avenues in employment; to go for higher studies; and to know about the subject in an in-depth manner. Learner support services include the following among others.

a) **KKHSOU City Campus:** The KKHSOU City Campus at Guwahati organises training for coordinators, counsellors, and other functionaries. The City centre provides a venue for learners and academic counsellors to interact on a particular subject matter. Responsibility for Admission, distribution of SLMs and Examination also lies with City Campus. Online counselling for all learners of all semesters of all programmes are centrally organised from city campus.

b) **Regional Centres:** The Regional centre of KKHSOU at Jorhat in upper Assam provides training for coordinators, counsellors, and other functionaries. The centre provides a venue for learners and academic counsellors to interact about a particular subject matter. Responsibility for Admission, distribution of SLMs and Examination in select districts of upper Assam also lies with Regional Centres. Establishment of some other regional centres is in the pipeline.

c) **Study Centres:** Study centres are the backbone of an open and distance learning institution. On behalf of the university, the study centres cater to the various requirements of learners, viz. Admissions-related information, delivering Self Learning Materials, conducting counselling sessions, distributing assignments and evaluating them, conducting term-end exams, etc. The study centers throughout the state handle these affairs on behalf of the University.

d) **Pre-enrolment Counselling:** In cooperation with study centres, the university provides pre-enrolment counselling for all the programmes through online and offline modes. It provides basic knowledge of the programmes, counselling sessions, etc. Moreover, programme specific pre-enrolment counselling is also organised.

e) **Sikshartha Mitra:** A few employees of the University have been engaged as Sikshartha Mitra in order to provide better technical support and assistance to the candidates during online admission process.

f) **Learners' Charter:** The University has brought out a Learners' Charter pronouncing the basic rights and responsibilities of its learners. In the Induction Programmes at the Study Centres, the learners are sensitized about this Charter.

g) **Handbook/SOP:** The University has brought out a Handbook for the Study Centres and a Standard Operating System (SOP) of Examination.

h) **Audio CDs for Visually Impaired Learners:** The visually impaired learners are provided with free audio SLMs in CDs to overcome their difficulties of learning. The University has installed Braille printers for this category of special learners in the University SLM branch.

i) **Face-to-face/Online Ticketing/Complaint System:** Learners' queries are attended in the face-to face mode and digital mode as well in a continuous way, through telephone,

SMS and emails. There is a dedicated online portal through which the queries received automatically move to concerned department for solving the same. Once the problem is solved, the learner is informed by SMS and email.

j) **Face to face and Walk-in Counselling:** Master of Science (Mathematics) learners will receive face-to face counselling from study centers. The University also provides face-to-face counselling/walk-in counselling to learners at the specially maintained city learner support center located at the city campus on Sundays or weekdays.

k) **ICT Support:** ICT support is a major component of any ODL system of education. Some of the ICT-based support systems provided by the university, which can be availed by the learners of Master of Science (Mathematics) are listed below:

- **Website:** The University has developed a full-fledged official website [www.kkhsou.in](http://www.kkhsou.in) for learners and the general public. The website has a dedicated Learners' Corner that contains exhaustive information and links to useful resources which is accessible to the vast learner population. Furthermore, the Website links to social-networking sites like Facebook where learners, faculty members, and stakeholders can interact. Additionally, the site offers a tailored search by district or programme. And most of the audio-visual programmes are accessible online through YouTube videos.
- **Community Radio Service:** Jnan Taranga (90.0 MHz) is the first Community Radio station in the North Eastern part of the country administered by the University. Community Radio, being a platform for the community for taking up community issues, is also a platform for broadcasting educational programmes. This includes debates, discussions, and talk shows.
- **e-Bidya:** As part of its ongoing attempts to enhance student learning, the university has developed a Learning Management System (LMS) portal called e-Bidya using open source MOODLE which can be accessed. The site allows learners to access e-resources 24 X 7, regardless of where they are in relation to the particular programme they are enrolled in. Learners can interact with experts in the discussion forum. Learners can experience the benefits of online learning through their mobile devices as well. The same facilities are being imparted for the Master of Science (Mathematics) programme as well.
- **Open Access Journals Search Engine (OAJSE):** The OAJSE ([www.oajse.com](http://www.oajse.com)) can be used to browse and search 4,775 Open Access Journals from the rest of the World excluding India, 532 journals from India, and 32 Indian Open Access Indian Repositories. It provides all pertinent information about KKHSOU's central library, including access to electronic resources, the Online Public Access Catalogue (OPAC), and subscribed journals and databases. It also provides an email alert service (current awareness service) to learners and is linked with major social networks including Facebook and Twitter.
- **KKHSOU Mobile App:** The university has developed a mobile application "KKHSOU" that allows students to access the university website 24x7.
- **SMS Alert Facility:** The University has implemented an SMS alert system for learners which notify of university news, events, and learner-related information.
- **E-Mentoring Groups:** The e-mentoring system, which utilizes the Telegram App/WhatsApp, helps learners acquire all the characteristics of open and

distance learners, so that they can continue their studies with self-confidence, self-esteem, morale, and a feeling of identity. It is the main objective of this initiative to help learners minimize personal difficulties and identify the obstacles they face due to the diverse needs and backgrounds they have. During this process, they are also guided to develop appropriate and suitable learning strategies for overcoming all these difficulties and problems.

- **E-mail:** Learners can also write emails to any officials/faculty members of the University. For this a general email ID: [info@kkhsou.in](mailto:info@kkhsou.in) has been created. Concerns raised through email to this email address are addressed by the University's relevant officials or faculty members. Apart from that, the email and phone numbers of all faculty members are available on the website and Information Brochure. Any learners can write directly to them as well.
- **Online Counselling:** The University's faculty conducts online counselling sessions through different online platform like Zoom, Google Meet, Cisco Webex and Face book etc. in addition to regular counselling sessions in study centers. It provides direct interaction of learners with the regular faculty members of the University which creates a greater sense of inclusion and reduces feelings of isolation by offering personal care and guidance to all learners.
- **KKHSOU in Social Media:** KKHSOU has incorporated social media sites like Facebook pages, Whatsapp group, Twitter Account that enables sharing and interaction with the students' community.

## 7. PROCEDURE FOR ADMISSION, CURRICULUM TRANSACTION ANDEVALUATION

### 7.1 Procedure for Admission

i. **Minimum Qualification:** The eligibility criteria for the Master of Science (Mathematics) to be offered by KKHSOU are:

- B. A./B.Sc. (Hons.) in Mathematics from any recognized Indian University.  
Or
- B.Sc./B. A. with Mathematics as one of the subjects of study from any recognized Indian University.

ii. **Online Admission:** Admission to this Master of Science (Mathematics) programme would be offered by KKHSOU through online in the University website: [www.kkhsou.ac.in](http://www.kkhsou.ac.in). A prospective learner may take admission as per his/her choice in KKHSOU City Study Centre, Khanapara, or any other recognized study centre for the Master of Science (Mathematics) programme in the State of Assam. A learner is to submit all relevant documents for admission through the online admission portal. The course fee is to be paid through credit card/ debit card/net banking or UPI- Bharat QR, BHIM, PhonePe, GPay, Paytm, WhatsApp and other UPI. After admission is done, a unique Registration / Enrolment Number is automatically generated which will have to be used for future communications with the University. Based on his/her choice, and operational conveniences, a learner shall be assigned to a particular study centre for availing of dedicated services and counselling/tutoring facilities. The newly admitted learners will receive the SLMs through a dedicated study centre and in certain cases

SLMs may be sent to the learners' home address also. e-SLMs are also available in the University website. The University has a Credit Transfer Policy which is being revised to facilitate course exemption in order to promote dual degree.

iii. **Refusal/Cancellation of Admission:** At the time of admission the candidate must submit a declaration that he/she is not pursuing more than two-degree programmes under KKHSOU/any other recognised University or Institution simultaneously. If any false declaration is detected at any stage, his/her admission/mark sheets/ certificates may be cancelled by the University.

iv. **Continuous Admission:** By paying the necessary fees, a learner can obtain admission to the next semester once a particular semester is completed. Admission to the subsequent semester is not determined by the results of the previous semester. One may take admission in the next semester even without appearing in the previous semester examination. The admission period should be continuous from the date of completion of the previous semester's exams until 60 days after the start date. Incomplete exams, including back papers, will be allowed to be taken up when announcements of examination results are made. Learners are advised to regularly visit the University's website ([www.kkhsou.ac.in](http://www.kkhsou.ac.in)) and maintain regular contact with their allotted study centres.

v. **Pursuing Two Academic Programmes Simultaneously:** As per UGC guidelines dated April 2022 a learner can pursue two academic programmes simultaneously, one in full time physical mode and another in Open and Distance Learning (ODL)/Online mode; or up to two ODL/Online programmes.

vi. **Fee Waiver for Differently Able Persons (DIVYANGJAN):** The fee waiver will be applicable for differently able learners in all semesters of the programme where he/she has enrolled. Such learners must submit 'Form no. IV' issued by the Social Welfare Department or Disability and a copy of the Certificate issued by the Department of Empowerment of Persons with Disabilities, Ministry of Social Justice and Empowerment, Govt. of India. The forms/certificates of differently able learners which are verified by the Social Welfare Department, Govt. of Assam will be allowed the fee waiver for the eligible learners of this Master of Science (Mathematics) Programme also.

vii. **Economically Weaker Section (EWS):** The learners applying for admissions in EWS category shall submit EWS documents as per the latest Govt. of Assam guidelines.

viii. **Fee Structure:** The fee structure of the Master of Science (Mathematics) programme would have a break-up across semesters of the programmes. The fee is inclusive of Enrolment fees, Course fee, Examination fee, Exam centre fee and Mark-sheet fee. Currently the fee charged for one semester of this Master of Science (Mathematics) is Rs 5500.

ix. **Financial Assistance:** The University offers free education to jail inmates and differently abled learners. At present, the University offers free of cost education to jail inmates in 16 district jails of the state. The University is in the process of including more numbers of Central/District Jails in the coming Academic Session.

## 7.2 Curriculum Transaction

i. **Activity Planner:** There will be an activity planner, which guides the overall academic activities in the Master of Science (Mathematics) programme. This will be released prior to the university's admission schedule. The CIQA office as per UGC

guidelines and the office of the Academic Dean would upload the Academic Plan and month wise Academic Calendar. This will enable learners to plan their studies and activities accordingly.

**ii. Self-learning Materials (SLMs):** SLMs are designed in such a way that learners can easily follow them. With the help of subject experts, SLMs are prepared with relevant and up to date information and facts.

**iii. Multimedia Materials:** Apart from printed SLM, the university provides audio-visual learning materials related to course content.

**iv. Induction and Counselling Sessions:** Induction sessions are conducted by university officials and faculty together. Counselling sessions are conducted by the Study Centres. Normally all counselling sessions are scheduled on Sunday. A face-to-face interaction between the learners and the counsellor takes place during the counselling session. This enables learners to clear their doubts with regard to the various courses provided to them. Apart from that, from time to time, online counselling sessions will be provided by the faculties of the University for this Master of Science (Mathematics).

**v. Web-based tools:** The University also provide Web Enabled Academic Support Portal through e-Bidya, the Learning management system of KKHSOU available at <https://www.lmskkhsou.in/web/> to access the course materials and other learning resources.

### 7.3 Evaluation

For this Master of Science (Mathematics) the general guidelines of the University will be followed. Vide are solution of the 33rd Meeting of the Academic Council and the subsequent approval of the Board of Management and as per UGC regulation (04-09-2020) Clause 15, KKHSOU has decided that the Total Marks for Internal (Formative) Assessment will be 30%, and that for Summative Assessment will be maximum 70% i.e. 30 marks and 70 marks out of Total 100marks. The University has adopted Letter Grades and Grade Points as per UGC Curriculum and Credit Framework for UG Programmes 2022. The summative assessment is conducted in those examination centres where the UGC recommended facilities are available. While setting the Question Papers and evaluating the Answer Sheets, the learning outcomes of the Programme and the Courses would be considered. Examination monitoring is an essential feature in conducting the examination processes. The University appoints Supervisory Officers, Examination Monitoring Officers and Examination Squads on a regular basis for smooth conduct of examinations. Some details of examination processes which would be applicable for this Master of Science (Mathematics) are presented below.

**Continuous and Comprehensive Formative Assessment:** Continuous and comprehensive evaluation is an important component of the total assessment process in KKHSOU. There is provision for self-evaluation based on the Self Learning Materials. The University has decided to adopt a mechanism for continuous evaluation of the Learners through a mix of various flexible methods. Considering the practical limitations of the learners and the difficulty of administering, the University has adopted the formative assessment mechanism with the following in view. The learners are communicated about the details through the university website, official notifications, study centres and social media. Assignments totaling 50 marks

(10+10+10+10+10) will be assigned for each course by the respective discipline. The formative assessment comprises:

- a. A closed-ended assignment directly derived from the course or study material = 10 marks
- b. Two open-ended assignments requiring analytical, opinionated, or reflective responses from the learner based on the course content = 20 marks
- c. An assignment pertaining to an environmental topic = 10 marks
- d. Additional assignments in lieu of multiple-choice question tests = 10 marks

The learner's marks will be allocated by the relevant study centers according to the breakdown provided for (a), (b), (c), and (d), totaling 50 marks, which will be automatically reduced to 30 marks by the system.

However, for courses with practical component, the distribution will be 50% weightage for theory, 30% weightage for practical and 20% weightage for internal assessment. Concerned study centres will arrange Personal Contact Programmes (Online or Offline) and the learners need to attend the same, as per UGC Guidelines. The coordinators of the study centres will submit the marks after assessments, through the Home Assignment portal of the University.

**Project Report:** A learner has to prepare a dissertation on a particular topic under the guidance of a professionally qualified supervisor/guide in Semester IV of this Master of Science (Mathematics) Programme. In this course, learners should take up a problem related to the subject area. They should devise instruments for the collection and interpretation of data and the preparation of research report. The length of the report may be between 60-70 pages.

## **8. REQUIREMENT OF THE LABORATORY SUPPORT AND LIBRARY RESOURCES**

### **8.1 Laboratory Support**

Although the courses within the proposed Master of Science (Mathematics) do not heavily rely on laboratory services, learners may be provided with support through computer laboratories. Access to these facilities is available at their respective study centres and the University's city campus. In Guwahati, the city campus boasts two cutting-edge computer laboratories equipped with free and open-source software, including a compiler for the C programming language—a crucial component of the programme's syllabus. Learners can utilize these resources for practice independently, even without direct laboratory support.

### **8.2 Library Resources**

Library services are offered to the learners of KKHSOU through physical library facilities in its recognized study centres and also through the central library, set up by the University at its city campus. Reference books are suggested by the faculty of the respective Disciplines/Schools of the University and also by the SLM writers. The Central Library at KKHSOU has a sizeable repository of relevant reference books and textbooks relating to the Master of Science (Mathematics) Programme. The central library KKHSOU is well-stocked with 19135 print books, 36 print journals on various disciplines and 8 Newspapers (as on 10-05-2024). The books available at the Central

Library are quite helpful not only for the learners, but also for the faculty members, SLM contributors and the content editors as well. Apart from the print resources, a good number of electronic resources comprising e-journals, online databases, gateway portal to e-journals are all made accessible to the learners. The learners are communicated once the subscriptions are made to the programme specific journals. The library is fully computerized with an ILS (Integrated Library System) and also equipped with RFID (Radio-Frequency Identification Technology). All the learners of the University including the learners of the Master of Science (Mathematics) can access the webpage of the University library at their own time and convenience. Moreover, the learners can take advantage of the facilities of the Digital Library (<http://dlkkhsou.inflibnet.ac.in/>). The digital library provides an online platform for collecting, preserving and disseminating the teaching, learning and intellectual output of the University to the global community including the KKHSOU learners. Beyond the physical boundary the library of KKHSOU has been maintained a web catalogue (<http://opac.kkhsou.ac.in/>) to facilitate the learners to browse library collection online.

The University has an OER Policy which spells out the learning material released by the university in physical or digital format. KKHSOU has signed Content Partner Agreement with National Digital Library of India to share its Digital Resources. The main objective of NDLI is to integrate several national and international digital libraries in one single web-portal. The learners community of KKHSOU can avail the services through a single window. The OAJSE ([www.oajse.com](http://www.oajse.com)) can be used to browse and search 4,775 Open Access Journals from the rest of the World excluding India, 532 journals from India, and 32 Indian Open Access Indian Repositories. It provides all pertinent information about KKHSOU's central library, including access to electronic resources, the Online Public Access Catalogue (OPAC), and subscribed journals and databases. It also provides an email alert service (current awareness service) to learners and is linked with major social networks including Facebook and Twitter. Online subscriptions of reputed journals and databases are regularly made. The learners would be communicated once the subscriptions are made to the programme specific journals.

## **9. COST ESTIMATE OF THE PROGRAMME AND THE PROVISIONS**

The office of the Finance Officer of KKHSOU keeps all the records of finances regarding print of SLMs, honorarium paid to the members of the Committee on Courses, honorarium paid to Content Writers, Content Editors, Language Editors, Translators, Proof Readers and also the expenditure related with organizing counsellors' workshops, meeting of the co-ordinators of the study centres etc. Moreover, the finance office also maintains records of purchase of computers, online space, books, journals etc. The accounts are maintained as per the laid down procedures of government. Regarding the cost of programme development, programme delivery, and programme maintenance, the finance office conducted an exercise based on historical costing method to arrive at indicative figures of cost. The findings are presented below in respect of the Master of Science (Mathematics) Programme.

### **9.1 Programme Development Cost**

#### **a) SLM Development Cost for Master Degree Programme**



Writing	4,000.00	
Content Editing	2,000.00	
Language Editing	1,000.00	
DTP (Avg. 40 pages per unit @ 15/- per page)	600.00	
<b>Total Cost(English Medium per Unit)</b>	<b>7,600.00</b>	

b) Printing Cost per SLM (for 1000 learners)

Printing (inside pages avg. 80 both side pages @ 690/- per page)	55,200.00	
Cover Page	5,850.00	
Binding	2,400.00	
Packing	5,500.00	
<b>Total</b>	<b>68,950.00</b>	

### 9.2 Programme Delivery Cost

The self-learning materials (SLMs) prepared for the Master of Science (Mathematics) need to be delivered to various study centers located in remote areas. On average, the university delivers about 2.2 kg of study materials per learner, per semester. The cost of delivering 2.2 kg of such materials is Rs. 60 per semester. Therefore, the total programme delivery cost for the Master of Science (Mathematics) per learner for four semesters is Rs. 240.

### 9.3 Programme Maintenance Cost

The University has made financial provisions for organizing stakeholder meetings, counselling workshops, and other activities as per the academic plan and academic calendar approved by the Academic Council. These workshops and meetings will not only benefit learners of the Master of Science (Mathematics) but also learners of other programmes. The University will also bear the cost of organizing the meetings of the Syllabus Revision Committee and providing additional study materials if required to improve the quality of the programme. Based on data from the University's finance department, the programme maintenance cost is Rs. 1,750.

## 11. QUALITY ASSURANCE MECHANISM AND EXPECTED PROGRAMME OUTCOMES

### (a) Quality Assurance Mechanism

With regard to quality assurance of all the Programmes of the University including the Master of Science (Mathematics), the University is involved in the following activities: The programme design and structure is decided upon after a series of

discussions and deliberations with a team of a few carefully chosen subject experts, who are mostly eminent scholars and professionals from the reputed institutions of higher education. Formed with due approval from the University authority, this Committee on Courses is helped by the in house discipline and School faculties while preparing the framework of the programme. The university has a SLM Policy which is followed in development of SLM. SLM Audit is a regular feature of the University which is conducted by CIQA. The course material writers and content editors are mostly in academics from reputed higher educational institutions. SLMs are distributed through a well laid down mechanism to all the learners by a mix of modes. Moreover, eSLM has been made available. Like the SLM Policy, the University has adopted University wide approaches for development of policies, Strategic Action Plan and their implementation. CIQA takes care of the following among others to enhance the quality of the various facets of the University:

- Counsellors' workshops
- Stakeholders' meetings
- Feedback responses from the learners from various programmes
- SLM Audit

In order to keep the programme on Master of Science (Mathematics) updated, the programme would be revised and necessary changes would be incorporated for the benefit of the learners, based on the inputs received from the mechanism as mentioned above. Learners' and stakeholders' feedback is regularly collected and based on that, remedial measures and improvement mechanisms are worked out.

#### **(b) Expected Programme Outcomes**

The expected programme outcomes of Master of Science (Mathematics) are:

- a) Apply mathematical concepts, tools, and techniques across interdisciplinary fields to address real-world problems effectively.
- b) Utilize mathematical skills for problem-solving and preparation for various competitive examinations.
- c) Recognize and apply mathematical applications in diverse disciplines, thereby enhancing career prospects across different fields and research domains.
- d) Possess foundational knowledge of programming and computational techniques essential for employment opportunities.
- e) Develop analytical prowess, critical thinking, creativity, and communication skills through assignments, seminars, and project work.
- f) Demonstrate proficiency in solving various theorems and proofs.
- g) Foster critical thinking abilities to conduct unbiased scientific investigations devoid of preconceived notions.
- h) Equip students with the skills to analyze problems, formulate hypotheses, evaluate and validate results, and draw reasonable conclusions.
- i) Prepare students for pursuing research or careers in mathematical sciences and related industries.
- j) Continuously acquire relevant knowledge and skills necessary for professional activities
- k) Foster awareness to become responsible citizens, committed to fulfilling their duties within the framework of their rights and privileges.
- l) Effectively communicate mathematical ideas and contribute to the dissemination and popularization of mathematical knowledge in society.

**ANNEXURE I**  
**Krishna Kanta Handiqui State Open University**  
**Curriculum Structure in**  
**Master of Science (Mathematics)**

**Credit Distribution for Master of Science (Mathematics)**

SL No	Nature of Courses	Total no. of Courses	Credit	Total Credits
1	DSC (Discipline Specific Core)	12	4	48
2	DSE (Discipline Specific Elective)	04	4	16
3	AEC (Ability Enhancement Course)	02	4	08
4	VAC (Value Added Course)	02	2	04
5	Seminar	01	4	04
6	Project/Dissertation	01	8	08
	Total	22		<b>88</b>

**Course Distribution for Master of Science (Mathematics)**

Semester	DSC	DSE	AEC	VAC	Dissertation/ Seminar	Semester wise credits
I	DSC 1, DSC 2, DSC 3	DSE 1	AEC 1	VAC 1		22
II	DSC 4, DSC 5, DSC 6	DSE 2		VAC 2	Seminar	22
III	DSC 7, DSC 8, DSC 9	DSE 3	AEC 2			20

IV	DSC 10, DSC 11, DSC 12	DSE 4			Project/Dissertation	24
<b>Total Credits</b>	48	16	08	04	12	<b>88</b>

### Semester-wise Course and Credit Distribution

Semester	DSC (Core) (12 Courses, Credit 4 each)	DSE (4 Courses, Credit 4 each)	AEC (2 Courses, Credit 4 each)	VAC (2 Courses, Credit 2 each)	Dissertation/ Seminar (Seminar: 4 Credit, Project: 8 Credit)	Total Credits
<b>I</b>	Abstract Algebra	Computer Programming using C	AEC 1	VAC 1		<b>22</b>
	Differential Equations					
	Real Analysis					
<b>II</b>	Complex Analysis	Operations Research		VAC 2	Seminar	<b>22</b>
	Introduction to Topology					
	Linear Algebra					
<b>III</b>	Functional Analysis	Measure theory and Integration  OR  Fluid Dynamics	AEC 2			<b>20</b>
	Classical Mechanics					
	Integral Equations and Calculus of Variation					
<b>IV</b>	Numerical Analysis and Computation	Differential Geometry  OR  Fuzzy Sets and Applications			Project/ Dissertation	<b>24</b>
	Number Theory					
	Graph Theory					
<b>Total Credit</b>	<b>48</b>	<b>16</b>	<b>8</b>	<b>4</b>	<b>12</b>	<b>88</b>

## Marks Distribution of Courses for Master of Science (Mathematics)

Course Code	Semester	Course	Whether DSC/DSE/AEC/VAC	Marks	Credit
	1 <sup>st</sup>	Abstract Algebra	DSC	30F+70S	4
		Differential Equations	DSC	30F+70S	4
		Real Analysis	DSC	30F+70S	4
		Computer Programming in C	DSE	20F+30P+50S	4
		AEC	AEC	30F+70S	4
		VAC	VAC	30F+70S	2
	2 <sup>nd</sup>	Complex Analysis	DSC	30F+70S	4
		Introduction to Topology	DSC	30F+70S	4
		Linear Algebra	DSC	30F+70S	4
		Operation Research	DSE	30F+70S	4
		VAC	VAC	30F+70S	2
		Seminar	Dissertation/ Seminar	100	4
	3 <sup>rd</sup>	Functional Analysis	DSC	30F+70S	4
		Classical Mechanics	DSC	30F+70S	4
		Integral Equations and Calculus of Variation	DSC	30F+70S	4
		(Choose any one) Measure theory and Integration Fluid Dynamics	DSE	30F+70S	4
		AEC	AEC	30F+70S	4
	4 <sup>th</sup>	Numerical Analysis and Computation	DSC	30F+70S	4
		Number Theory	DSC	30F+70S	4
		Graph Theory	DSC	30F+70S	4
		(Choose any one) Differential Geometry Fuzzy Sets and Applications	DSE	30F+70S	4
		<b>Major Project</b>		200	8
					<b>88</b>

**N.B.:**

F = Formative Assessment (i.e., Internal Assessment)

P = Practical (Summative Assessment)

S = Summative Assessment (i.e., End Semester Examination)

1 credit = 30 hours of learning

4 credits =  $30 \times 4 = 120$  hours of learning

**ANNEXURE II**  
**Master of Science (Mathematics)**

**DETAILED COURSE WISE SYLLABUS**  
**Syllabus of Discipline Specific Core (DSC) Courses**

**SEMESTER I: Abstract Algebra**

Course Type:	<b>DSC</b>
Number of Credits:	<b>4</b>
Total Marks:	<b>100 (I.A:30, E.S.E: 70)</b>

Course Objectives: The course will enable the learners to

- study Group action and permutations representations,
- Cayley's theorem, class equation, the fundamental theorem of finitely generated abelian group, p-groups, solvable
- groups, polynomial rings over a field, Subfield and prime fields, extensions of fields.

Course Outcomes: After successful completion of this course, the learner will able to

- Describe the Group theoretic notions of class equation and the related results.
- Discuss three important classes of Ring structures, viz., the principal ideal Domain, Euclidean domain and the unique factorization domain.
- Familiarize with group action, groups acting on themselves by conjugation.
- Understand direct products, the fundamental theorem of finitely generated abelian group, p-groups, solvable groups.
- Familiarize with Eisenstein's criterion for irreducibility of  $(x) \in [x]$  over  $\mathbb{Q}$ , roots of polynomials.
- Familiarize with subfield and prime fields.

**Unit 1: Introduction to Groups**

Groups, subgroup, Cyclic groups

**Unit 2: Lagrange's Theorem, Normal subgroup and Quotient Groups**

Cosets, Lagrange's Theorem, normal subgroup, Quotient Groups

**Unit 3: Permutation Groups**

Permutation Groups, Alternating group  $A_n$

**Unit 4: Homomorphisms of Groups**

Homomorphism of groups, Types of Homomorphism, Properties of Homomorphism

**Unit 5: Direct Products of Groups and Finite Abelian Groups**

External direct products of Groups, Internal Direct products, Structure of Finite Abelian

groups

### **Unit 6: Group Series and Structure**

Normal and Subnormal series, Composition Series, Zassenhaus Lemma, Schreier's refinement theorem, Jordan-Holder theorem, Commutator subgroup, Solvable Groups, Nilpotent groups

### **Unit 7: Class Equation and Cauchy's Theorem**

Class equation, Cauchy's theorem, Sylow p-subgroups and its applications

### **Unit 8: Group Actions and Sylow Theorems**

Group Actions, Sylow's theorem, Application of Sylow's theorem

### **Unit 9: Rings, Integral Domains and Fields**

Rings, Subrings, Integral Domains, Fields, Characteristic of Rings, Ideals

### **Unit 10: Factor Rings and Ring Homomorphism**

Factor Ring, Ring Homomorphism, Isomorphism Theorems

### **Unit 11: Polynomial Rings**

Polynomial Rings, Irreducible Polynomials, Irreducibility Tests, Structure of Finite fields

### **Unit 12: Factorization in Integral Domains and Field Extensions**

Associates, Irreducible, and primes, Principal Ideal Domains, Unique Factorization Domains, Euclidean Domains, Field Extensions

### **Unit 13: Splitting Field**

Concept of splitting field, Examples of splitting field

### **Unit 14: Normal Extensions and Perfect Fields**

Normal extensions, Perfect fields, Finite fields, Primitive elements, algebraically closed fields, Automorphisms of extensions

### **Unit 15: Galois Groups and Galois Extensions**

Galois Groups, Galois Extensions

#### ***Suggested Readings:***

1. Gallian, J. A. *Contemporary Abstract Algebra*. 9th edition. Cengage Learning, 2015.
2. Lang, S. *Algebra*. 3rd edition, Springer 2012.
3. Herstein, I. N. *Topics in Algebra*. 2nd edition. John Wiley and Sons, 2006.



4. Bhattacharya, P. B. Jain, S. K. and Nagpaul, S. R. *Basic Abstract Algebra*. 2nd edition, Cambridge University Press, 2003.
5. Khanna, V. K. and Bhammbri, S. K. *A Course in Abstract Algebra*. Vikas Publishing house, 1999.
6. Cohn, P. M. *Algebra*. Vols. I & II, John Wiley & Sons, 1991.
7. Luther, S. and Passi, I. B. S. *Algebra*. Vol. I-Groups, Vol. II-Rings, Narosa Publishing House (Vol. I – 1996, Vol. II –1990).
8. Hungerford, T. W., *Algebra*. (1974). Springer-Verlag. New York.
9. D.S. Dummit and R.M. Foote, *Abstract Algebra* (3rd Edition), Wiley, 2011
10. N. Jacobson, *Basic Algebra I* (3rd edition), Hindustan Publishing corporation, New Delhi, 2002.
11. J. B. Fraleigh, *A First Course in Abstract Algebra* (4th edition), Narosa Publishing House, New Delhi, 2002.
12. J.J. Rotman: *An Introduction to the theory of groups*, Springer, 1994.

## SEMESTER I: Differential Equations

Course Type:	DSC
Number of Credits:	4
Total Marks:	100 (I.A.:30, E.S.E: 70)

Course Outcomes: After successful completion of this course, the learner will able to

- study Initial Value Problems (IVP),
- second order differential equations and few methods to solve Partial Differential Equations (PDE).

Course Outcomes: After successful completion of this course, the learner will able to

- Solve IVP.
- Solve elliptic, parabolic and hyperbolic differential equations.
- Monge's method to solve non-linear PDEs.
- Reducing the PDEs into its canonical forms.
- Solve PDE by separation of variables method.
- Apply various power series methods to obtain series solutions of differential equations.
- Determine the solutions of linear PDE's of second and higher order with constant coefficients, classify second order PDE's, solve standard PDE using separation of variable method and reduction to canonical form.
- Solve the first-order linear and non-linear PDE's by using Lagrange's, Charpit's method and Jacobi's method respectively.

### Unit 1: Introduction to differential Equations

Definition and Classification of differential equations, order and degree of differential equation, Initial value problem (IVP) and boundary value problems (BVPs)

### Unit 2: Differential Equations of First order and First Degree

Variable Separable Method, Homogeneous Differential Equation, Linear Differential Equation, Bernoulli's equation

### Unit 3: Exact Differential Equation of first order and first degree

Exact differential Equations, Equation reducible to exact equations

### Unit 4: Existence and Uniqueness

Well posed problems, Lipschitz condition, existence and uniqueness theorem for first order equations. Picard's method, Initial value problems for second order equations; existence theorem; uniqueness theorem; linear dependence and independence of solutions; Wronskian

**Unit 5: Higher Order Linear Differential Equations**

Homogeneous and non-homogeneous linear Differential Equations, Method of undetermined coefficients, Method of variation of parameter

**Unit 6: Orthogonality and Independence in ODES**

Orthogonality of functions, Orthonormal set of functions, Singular solutions of first order ODEs

**Unit 7: First order Linear partial Differential Equations**

Formulation and origin of First order PDEs, Solution of a PDE, Solutions to linear PDEs of first order

**Unit 8: Second order Partial Differential Equations with constant coefficients**

Partial Differential Equations of Second Order: Linear partial differential equations of second order with constant co-efficient, Characteristic curves of second order equations, Reduction to canonical forms, Separation of variables, Solutions of nonlinear equations of the second order by Monge's method

**Unit 9: Higher Order linear PDEs**

Introduction to higher order PDEs, Method of separation of variables, Canonical form and reduction to canonical forms

**Unit 10: First order Nonlinear PDE-I**

Cauchy's Method of Characteristic, Charpit's method and Jacobi method, special types of first order PDEs,

**Unit 11: Nonlinear First Order PDE-II**

Complete Integrals, Envelopes, Characteristics,

**Unit 12: Elliptic Differential Equations**

Elliptic differential equations. Occurrence and detailed study of the Laplace and the Poisson equation. Maximum principle and applications, Green's functions and properties.

**Unit 13: Parabolic Differential Equations**

Parabolic differential equations. Occurrence and detailed study of the heat equation. Maximum principle. Solutions of IVPs for heat conduction equation. Green's function for heat equation, Duhamel's principle.

**Unit 14: Hyperbolic Differential Equations**

Hyperbolic differential equations. Occurrence and detailed study of the wave equation. Solution of three-dimensional wave equation. Method of descent and Duhamel's principle. Solutions of equations in bounded

***Suggested Readings:***

1. Simmons, G. F. *Differential Equations with Applications and Historical Notes*. 2nd edition, Tata McGraw Hill, New Delhi, 2016.
2. Evans, L. C. *Partial Differential Equations*. 2nd edition, The Orient Blackswan, 2014.
3. Lebedev, N. N. *Special Functions and Their Applications*. Revised, Courier Corporation, 2012.
4. Ross, S. L. *Differential Equations*. 3rd edition, Wiley India, 2007.
5. Sneddon, I. N. *Elements of Partial Differential Equations*. Dover Publications, 2006.
6. Bell, W. W. *Special Functions for Scientists and Engineers*. Courier Corporation, 2004.
7. Raisinghania, M. D. *Advanced Differential Equations*. S. Chand & Company Ltd., New Delhi, 2001.
8. Reid, W. T. *Ordinary Differential Equations*. John Wiley and Sons, New York, 1971.
9. E.A. Coddington, *An Introduction to Ordinary Differential Equations*, Dover Publications
10. T. Myint-U, *Ordinary Differential Equations*, Elsevier, North-Holland, 1978.
11. Bhamra, K. S. (2010), *Partial Differential Equations*, PHI Learning Pvt. Ltd.

## SEMESTER I: Real Analysis

Course Type:	DSC
Number of Credits:	4
Total Marks:	100 (I.A.:30, E.S.E: 70)

Course Objectives: The course will enable the learners to

- introduce the basic concept of uniform convergence of sequence and series of functions, power series,
- Describe the properties of the Real numbers
- Analyze the properties of advanced differentiation and Integration of real valued functions in one or multiple variables

Course Outcomes: After successful completion of this course, the learner will able to

- Use of uniform convergence of sequence and series of functions
- Use of exponential and logarithmic functions, trigonometric functions, Fourier series to solve problems
- Use of bounded variations, Reimann-Stieltjes integral and their applications
- Recognize bounded, convergent, divergent, Cauchy and monotonic sequences. To calculate the limit superior, limit inferior of sequences and limit of a bounded sequence.
- Recognize bounded variation, total variation, directional derivatives, partial derivative and derivative as a linear transformation.

### UNIT -1: Real Number System-I

Field axioms, some properties of real numbers, Absolute value or modulus of real number, Bounded and unbounded subsets of real numbers, least upper bound or supremum, Greatest lower bound or infimum, Some properties of supremum and infimum, Completeness axiom, The set of real number as a complete ordered field, Archimedean property of real numbers, The denseness property of the real number system

### UNIT -2: Real Number System-II

Neighbourhood of a point, Limit points of a set, Bolzano Weierstrass theorem, Interior of a set, Open sets, Closed sets, Closure of a set, Countability of sets, Dedekind's property of real numbers

### UNIT-3: Sequence

Sequence, Subsequence, Bounded sequences, Convergent sequences, Divergent Sequences, Algebra of convergent sequences, Monotonic sequences, Limit point of a sequence, Cauchy's sequences, Cauchy's general principle of convergence, Limit superior and limit inferior of a sequence, Nested interval theorem or Cantor's intersection theorem

**Unit-4: Infinite Series-I**

Convergent and divergent series, Cauchy's general principle of convergence for series, The auxiliary Series  $\sum \left(\frac{1}{n^p}\right)$

**Unit-5: Infinite Series-II**

Comparison test, Cauchy's root test, D'Alembert's ratio test, Cauchy's condensation test, Raabe's test, Logarithmic test, De Morgan's test and Bertrand's test, Gauss's test, Cauchy Maclaurin's integral test, Alternating series, Alternating series test (Leibnitz's test), Absolute convergence and conditional convergence

**Unit-6: Power Series**

Power series, Radius of convergence, Uniqueness of power series, Properties of power series

**UNIT-7: Limits of Functions**

Limit, Algebra of limits of functions, Right hand and left-hand limits, Infinite limit,

**Unit -8: Continuous Functions**

Cauchy's definition of continuity, Types of discontinuity, Algebra of continuous functions, Properties of continuous functions, Uniform continuity

**UNIT-9: Differentiable Functions**

Derivative of a point, Derivative of a function, A necessary condition for the existence of finite derivative, Algebra of derivatives, Rolle's theorem, Lagrange's mean value theorem, Cauchy's mean value theorem, Taylor's theorem with Lagrange's form of remainder, Taylor's theorem with Cauchy's form of remainder, Taylor's series, Maclaurin's series

**Unit 10: Functions of Several Variables**

Structure of  $R^n$ , Limit, continuity of functions of  $R^n$  to  $R$ , Directional derivatives and Partial derivatives,

**UNIT-11: The Riemann Integral**

Partitions and Riemann sums, Upper and lower Riemann integrals, Riemann integrability, Riemann's necessary and sufficient conditions for R-integrability, Some classes of integrable functions, Fundamental theorem of integral calculus

**UNIT-12: The Riemann-Stieltjes integral**

A generalization of the Riemann integral, Partitions, Lower and upper Riemann-Stieltjes integrals, The Riemann-Stieltjes integral, The RS-integrals as a limit of sums, Some classes of RS-integrable functions, A relation between R-integral and RS-integral

**UNIT-13: Uniform convergence of sequences and series**

Uniform convergence, Cauchy's general principle of uniform convergence, Tests for uniform convergence, Uniform convergence and continuity, Uniform convergence and integration, Uniform convergence and differentiation

#### **UNIT-14: Convergence of Improper integrals**

Convergence of improper integrals, Tests for convergence of improper integrals of the first kind, Absolute convergence, Tests for convergence of improper integrals of the second kind

##### ***Suggested Readings:***

1. Walter, R. *Principles of Mathematical Analysis*. 3rd edition, McGraw-Hill, 2017.
2. Terence T. *Analysis II*. Hindustan Book Agency, 2009.
3. Malik, S. C. and Arora, S. *Mathematical Analysis*. 2nd edition reprint. New Age International Publishers 2005.
4. Apostol, T. M. *Mathematical Analysis*. 2nd edition. *Wesley Publishing Co.* 2002.
5. Somasundram, D. and Chaudhary, B. *A First Course in Mathematical Analysis*. Narosa Publishing House, 1996.
6. Royden, H. L. *Real Analysis*, Macmillan Pub. Co., Inc. 4th edition, New York, 1993.
7. Bartle, R. G., Sherbert, D. R. (2011). *Introduction to real analysis*. Hoboken, NJ: Wiley.
8. Narayan, S., Raisinghania, M.D. *Elements of Real Analysis*. S. Chand & Company Pvt.Ltd.2015.

## SEMESTER II: Complex Analysis

Course Type:	DSC
Number of Credits:	4
Total Marks:	100 (I.A:30, E.S.E: 70)

Course Objectives: The course will enable the learners to

- familiarize the learner with complex function theory, analytic functions theory, the concept of index and Cauchy's theorems, integral formulas, singularities and contour integrations and finally provide a glimpse of maximum principle and Schwarz' lemma.

Course Outcomes: After successful completion of this course, the learner will able to

- understand analytic function as a mapping on the plane, Mobius transformation and branch of logarithm.
- understand Cauchy's theorems and integral formulas on open subsets of the plane.
- understand how to count the number of zeros of analytic function giving rise to open mapping theorem and Goursat theorem as a converse of Cauchy's theorem.
- know about the kind of singularities of meromorphic functions which helps in residue theory and contour integrations.
- handle integration of meromorphic function with zeros and poles leading to the argument principle and Rouché's theorem.
- Analyze the concept of differentiability, analyticity, Cauchy-Riemann equations and harmonic functions.
- Understand the concept of bilinear transformation and conformal mapping.

### Unit 1: Functions of a complex variable

Functions of a complex number, Continuity and differentiability of complex function

### Unit 2: Analytic Functions

Analytical function, Conjugate function, Harmonic function,

### Unit 3: Cauchy -Riemann Equations

Cauchy-Riemann equations, Polar form of Cauchy-Riemann equations, Construction of analytical functions

### Unit 4: Power Series

Power series, Absolute Convergence, Some special tests for convergence of power series, Radius of convergence of power series

### Unit 5: Conformal Representation

Definitions and examples of Conformal transformation, Some general transformation, Bilinear transformations, their properties and classifications



**Unit 6: Complex integration**

Definite integrals, Contours, Contour integrals, Antiderivative, Cauchy-Goursat theorem

**Unit 7: Cauchy Integral Formula**

Cauchy's integral formula, Extended Cauchy integral formula, Higher order derivatives in the context of Cauchy's Formula

**Unit 8: Liouville's Theorem and Fundamental Theorem of Algebra**

Liouville's theorem, The fundamental theorem of algebra

**Unit 9: Taylor and Laurent Series**

Taylor series, Laurent series

**Unit 10: Zeros and Singular point**

Zeros of Analytical functions, Singular points, Different types of singular point

**Unit 11: Poles and Singularities**

Poles, Singularities, Types of singularities

**Unit 12: The calculus of Residue**

Residue, Cauchy's residue theorem, Residue at infinity, Residue at poles, Zeros and poles

**Unit 13: Application of Residues-I**

Evaluation of improper integrals, Integrals involving sines and cosines

**Unit 14: Application of Residues-II**

Argument principle, Rouché's theorem

**Suggested Readings:**

1. Saff, E. B. and Snider, A. D. *Fundamentals of Complex Analysis with Applications to Engineering and Sciences*. Pearson Education, 2014.
2. Conway, J. B. *Functions of One Complex Variable*, Springer, 2012.
3. Mathews, J. H. and Howell, R. W. *Complex Analysis for Mathematics and Engineering*. Jones & Bartlett Publishers, 2012.
4. Brown, J. B. and Churchill, R. V. *Complex Variables and Applications*. 8th edition, Tata McGraw-Hill Education, 2009.
5. Ponnusamy, S. *Foundations of Complex Analysis*. Alpha Science International, 2005.
6. Copson, E. T. *Theory of Functions of Complex Variables*. Oxford University Press, 1970.
7. L.V. Ahlfors, *Complex Analysis*, Mc Graw Hill Co., Indian Edition, 2017.
8. J.B. Conway, *Functions of One Complex Variable*, Second Edition, Narosa, New Delhi, 1996.
9. T.W. Gamelin, *Complex Analysis*, Springer, 2001.
10. L. Hahn, B. Epstein, *Classical Complex Analysis*, Jones and Bartlett, 1996.
11. M. Spiegel: *Complex variables*, Schaum's outline 2017, second edition.

## SEMESTER II: Introduction to Topology

Course Type:	DSC
Number of Credits:	4
Total Marks:	100 (I.A:30, E.S.E: 70)

Course Objectives: The course will enable the learners to

- introduce basic concepts of point set topology, basis and subbasis for a topology and order topology.
- study continuity, homeomorphisms, open and closed maps, product and box topologies and introduce notions of connectedness, path connectedness, local connectedness, local path connectedness, convergence, nets, countability axioms and compactness of spaces.
- introduce the basic concept of product topology, continuity and related concepts, product topology and box topology; Metric topology, Quotient topology, Connected spaces, local path connectedness etc.

Course Outcomes: After successful completion of this course, the learner will able to

- determine interior, closure, boundary, limit points of subsets and basis and subbasis of topological spaces.
- check whether a collection of subsets is a basis for a given topological spaces or not, and determine the topology generated by a given basis.
- identify the continuous maps between two spaces and maps from a space into product space and determine common topological property of given two spaces.
- determine the connectedness and path connectedness of the product of an arbitrary family of spaces.
- find Hausdorff spaces using the concept of net in topological spaces and learn about 1st and 2nd countable spaces, separable and Lindelöf spaces.
- learn Bolzano–Weierstrass property of a space and prove Tychonoff theorem.

### Unit 1: Closed and Open Set in $\mathbb{R}$

Real line, open and closed interval, Neighbourhood of a point, properties of a neighbourhoods, Upper bound, Lower bound, Supremum, Infimum, Bounded below, Unbounded, Limit point, closed set, open set, Derived set, Bolzano weierstrass Theorem

### Unit 2: Metric Space-I

Definitions, Examples and Theorems –Open sets, Accumulation points, Derived Set, Closed sets, Closure. Dense subsets.

### Unit 3: Metric Space-II

Neighborhoods. Interior, exterior and boundary. Points, Convergent sequences, Coarser and finer topologies. Metrics on Products, Incomplete and Complete Metric Spaces

**Unit 4: Topological Spaces**

Topology, T-open sets, Weaker and Stronger topology, Indiscrete and discrete topology, Co-finite topology, Usual topology, Open sets, Closed sets, Neighbourhood, Closure, Interior, Limit point

**Unit 5: Bases, Sub-bases and Countability**

Base, Sub-base, Local base, first countable, second countable theorem

**Unit 6: Continuous Functions**

Continuity, sequentially continuous, Homeomorphism, Topological property, open and closed maps, Uniform continuity

**Unit 7: Separation Axioms-I**

$T_0, T_1, T_2$  Spaces, normal spaces, Housdorff Spaces, Regular Spaces

**Unit 8: Separation Axioms-II**

$T_3, T_4$ -Spaces, completely regular Spaces, Tychonoff Space, completely normal  $T_0$  Space

**Unit 9: Compactness-I**

Cover, Open Cover, finite sub-cover, reducible, compact sets, finite intersection property, locally compact, Bolzano Weierstrass property

**Unit 10: Compactness-II**

Sequentially compact, Compactness for continuous images, Compactness for metric space

**Unit 11: Completeness of a metric space**

Cauchy sequence, Bair's category, Contraction map, Cantor's intersection theorem, Bair's category theorem, Ascoli's theorem

**Unit 12: Connectedness in topological spaces**

Separated sets, Disconnectedness, totally disconnected, Maximal connected set, Components, Path connectedness, Local connectedness

**Unit 13: Quotient and Product topology**

Product topology, Projection map, Quotient spaces

**Unit 14: Metrization**

Metrization, Uryshohn's metrization theorem

**Suggested Readings:**

1. Joshi, K. D. *Introduction to General Topology*. 2nd edition, New Age International Private Limited, 2017.
2. Munkres, J. R. *Topology*. Pearson Education, 2017.
3. Simmons, G. F. *Introduction to Topology and Modern Analysis*. Tata McGraw-Hill Education, 2016.

4. Pervin, W. J. *Foundations of General Topology*. Academic Press, 2014.
5. Singh, T. B. *Elements of Topology*. CRC Press, Taylor Francis, 2013.
6. G.E. Bredon, *Topology and Geometry*, Springer, 2014.
7. J. Dugundji, *Topology*, Allyn and Bacon Inc., Boston, 1978.
8. J.L. Kelley, *General Topology*, Dover Publications, 2017.
9. T.B. Singh, *Elements of Topology*, CRC Press, Taylor & Francis, 2013. [6] S. Willard, *General Topology*, Dover Publications, 2004.
10. J. R. Munkres, *Topology:a first course* , Prentice-Hall of India Ltd., New Delhi, 2000
11. J. L. Kelley, *General Topology*, Springer Verlag, New York, 1990.
12. K.D. Joshi, *Introduction to General Topology*, Wiley Eastern Ltd., 1983.
13. Crump W. Baker, *Introduction to Topology*, Wm C. Brown Publisher, 1991.
14. M.J. Mansfield, *Introduction to Topology*, D. Van Nostrand Co. Inc. Princeton, N.J., 1963.
15. B. Mendelson, *Introduction to Topology*, Allyn & Bacon Inc., 1962.
16. Seymour Lipschutz, *General Topology*, Schaum's Outline Series, 1981

## SEMESTER II: Linear Algebra

Course Type:	DSC
Number of Credits:	4
Total Marks:	100 (I.A:30, E.S.E: 70)

Course Objectives: The course will enable the learners to

- introduce the basic concept of matrix of a linear operator, eigen values and eigen vectors, diagonalization, Jordan canonical form, Bilinear form, symmetric form, Hermitian form, orthogonality,

Course Outcomes: After successful completion of this course, the learner will able to

- Learn about eigen values and eigen vectors of a linear operator and a matrix, learn about the diagonalization of a matrix and find the Jordan canonical form of a matrix.
- Describe the concepts of the term's basis, dimension, and apply these concepts to various vector spaces and subspaces.
- Use the concept of linear transformations, matrix representation and change of basis, including kernel, range.
- Understand the notion of bilinear forms, triangularization and primary decomposition theorem
- Compute inner products and determine orthogonality on vector spaces, applying Gram-Schmidt orthogonalization process to find the orthonormal basis.

### Unit 1: Vector Spaces and Subspaces

Vector space, Subspace, Linear combination, Linear span, Linear Sum, Direct Sum, Complimentary subspaces, Disjoint spaces, Quotient space

### Unit 2: Linear Dependence

Zero vector, operations on vectors, Vectors in  $C^n$ , Vectors in  $R^n$ , Unit vector, Orthogonality of two vectors, Linear dependence of vector, Linear independence of vector

### Unit 3: Basis and Dimension

Basis, finitely generated spaces, Dimension of vector space, Rank of a matrix, Existence theorem

### Unit 4: Linear Transformation

Transformation, Linear transformation, Isomorphism, Range space of linear transformation, Nullity and rank, Singular and non-singular transformation

### Unit 5: Matrix Representation of a linear transformation

Co-ordinate vector, Matrix representation of a transformation, Matrix representation of a linear operator, Change of Basis, Similar matrices, Determination of a linear transformation, Similarity of linear map

### Unit 6: Linear Functionals and the dual spaces

Linear functional, Dual space, Dual basis, Natural mapping and Reflexivity, Transpose

of a linear map, Annihilator, Adjoint of an operator

**Unit 7: Bilinear forms and Quadratic forms**

Bilinear form, Symmetric form, Antisymmetric form, Quadratic matrix, Quadratic forms, Matrix representation of bilinear form

**Unit 8: Projection and Invariance**

Idempotent and Nilpotent operators, Invariance, Reducibility, Projection

**Unit 9: Canonical Form-I**

Diagonal Form, Triangular Form, Nilpotent Transformation

**Unit 10: Canonical Form-II**

Jordan Canonical Form, Rational Canonical Form

**Unit 11: Inner Product Spaces-I**

Inner product, Norm, Orthogonality, Angle, Invariant

**Unit 12: Inner product Spaces-II**

Normed vector space, Complete orthonormal set, Self-adjoint operator, Bessel's inequality, Gram Schmidt orthogonalization process

**Unit 13: Eigen Values and Eigen Vectors-I**

Polynomial of matrices and linear operators, Eigen value and Eigen Vector, Matrix Polynomial, Characteristic subspace of a matrix, Eigenspace,

**Unit 14: Eigen Values and Eigen Vectors-II**

Minimal polynomial of a linear operator, Diagonalization of a linear operator, Diagonalizable matrix, Spectrum

***Suggested Readings:***

1. Hoffman, K. and Kunze, R. *Linear Algebra*. 2nd edition, Pearson India, 2015.
2. Axler, S. *Linear Algebra Done Right*. 2nd edition, Springer-Verlag, 2014.
3. Lang, S. *Linear Algebra*. 3rd edition, Springer-Verlag, New York, 2013.
4. Lipschutz, S. and Lipson, M. *Linear Algebra*. 3rd edition, Tata McGraw-Hill, 2005.
5. Friedberg, S. H., Insel, A. J. and Spence, L. E. *Linear Algebra*. 4th edition, 2002

## SEMESTER III: Functional Analysis

Course Type:	DSC
Number of Credits:	4
Total Marks:	100 (I.A:30, E.S.E: 70)

Course Objectives: The course will enable the learners to

- introduce the basic concept of topological algebraic structures namely normed linear spaces, Banach spaces, inner product spaces and Hilbert spaces.
- introduce the basic idea of continuous linear transformations between normed linear spaces, Hahn Banach theorem which allows extension of a bounded linear functional from a subspace of a normed space to the whole space.
- introduce Open mapping theorem, Closed Graph theorem and uniform boundedness theorem

Course Outcomes: After successful completion of this course, the learner will able to

- verify the requirements of a norm, completeness with respect to a norm, relation between compactness and dimension of a space, check boundedness of a linear operator and relate to continuity, convergence of operators by using a suitable norm, compute the dual spaces.
- distinguish between Banach spaces and Hilbert spaces, decompose a Hilbert space in terms of orthogonal complements, check totality of orthonormal sets and sequences, represent a bounded linear functional in terms of inner product, classify operators into self-adjoint, unitary and normal operators.

### Unit -1: Normed linear Space and relate theorems

Normed linear space and its properties

### Unit -2: Banach Space

Inequalities, Examples of Banach Space, Factor Space, Conjugate Space, Conjugate space  $C[a, b]$

### Unit-3: Bounded Linear Operators

Definitions, Examples and Basic properties, Space of Bounded linear operators, Equivalent Norms

### Unit-4: Bounded Linear Functionals

Definitions, Examples and Basic properties

### Unit -5: Uniform Boundedness Theorem

Uniform boundedness theorem and some of its consequences

### Unit -6: Open mapping theorem

Open mapping Theorem and its consequences

### Unit -7: Closed graph theorems

Closed graph theorem and its consequences

**Unit -8: Hilbert Space –I**

Inner product, Inner product in a normed space, Orthonormal Vectors, Bessel's inequality, Hilbert space

**Unit -9: Hilbert Space-II**

Orthogonality of Vectors, Orthogonal Complements and Projection Theorem, Orthonormal sets, Complete Orthonormal Sets, A representation theorem on Hilbert space, Reflexivity of Hilbert space

**Unit -10: The  $L^p$  Space**

Properties of  $L^p$  Space, Relations between  $L^p$  Spaces, Convergence in  $L^p$  Space

**Unit -11: Weak Convergence and  $Weak^*$  Convergence**

Weak convergence in Normed Space, Convergence of Sequences of Operators, Weak convergence in Hilbert space, Weak Compactness in Hilbert Space

**Unit-12: Functionals and Operators on Hilbert Space**

Adjoint of an Operator, Self-adjoint Operator, Positive Operator, Normal and Unitary Operators, Orthogonal Projection

**Unit-13: Finite-dimensional Spectral theory**

Eigenvalues of a Linear Operator, Eigen vectors, Matrix of an operator, The Spectral theorem

**Unit-14: Fixed point theorem and its application on the space of Continuous functions**

Fixed point theorem, Application of fixed-point theorem

**Suggested Readings:**

1. W. Rudin, *Functional Analysis*, McGraw Hill Education, 2017
2. B. V. Limaye, *Functional Analysis*, Willy Eastern Ltd., 1991.
3. C. Goffman and G. Pedrick, *First course in Functional Analysis*, Prentice-Hall of India Pvt. Ltd, New Delhi, 1974.
4. G. Bachman and L. Narici, *Functional Analysis*, Dover Publications, 2000.
5. R. Bhatia, *Notes on Functional Analysis*, Hindustan Book Agency, India, 2009.
6. E. Kreyszig, *Introductory Functional Analysis with Applications*, John Wiley & Sons, India, 2006.
7. M. Schechter, *Principles of Functional Analysis*, Second Edition, American Mathematical Society, 2001
8. C. Goffman and G. Pedrick: *First Course in Functional Analysis*, Prentice Hall of India, New Delhi, 1987.



## SEMESTER III: Classical Mechanics

Course Type:	<b>DSC</b>
Number of Credits:	<b>4</b>
Total Marks:	<b>100 (I.A:30, E.S.E: 70)</b>

Course Objectives: The course will enable the learners to

- Comprehend and apply conservation principles governing mechanics, including conservation of linear momentum, angular momentum, and energy
- Understand and apply the Hamiltonian formulation in dynamics, including generalized momentum, conservation theorems, and Hamiltonian equations in different coordinate systems
- Understand and apply variational principles like Euler-Lagrange's and Hamilton's principles in solving dynamic systems
- Solve problems using Hamilton-Jacobi equation particularly in harmonic oscillator and Kepler's problem
- Understand the dynamics of rigid bodies, their generalized coordinates, angular momentum, inertia tensor, and kinetic energy.

Course Outcomes: After successful completion of this course, the learner will be able to

- Apply conservation laws to analyze and solve problems related to linear momentum, angular momentum and energy conservation
- Apply Newton's laws of motion to understand and solve problems in central force fields and related motion
- Formulate and solve dynamic problems using Lagrange's and Hamilton's equations for systems with constraints
- Apply variational principles to derive and solve dynamic systems using Euler-Lagrange and Hamilton's principles
- Analyze the dynamics of rigid bodies, understand their properties and solve related problems

### Unit 1: Basic Concepts

Newton's law of motion, Motion in a central Force Field, Conservative force

### Unit 2: Mechanics of a particle and system of particles

Conservation principle (laws), Mechanics of a particle, Conservation of linear momentum, Conservation of angular momentum, Work, Power and Energy, Conservation of energy, Mechanics of a system of particles

### Unit 3: Lagrangian Formulation of Dynamics-I

Constraints, Type of constraints, degree of freedom, Generalized co-ordinates, Principle of virtual work, D'Alembert's Principle, Lagrange's equation for holonomic constraints

**Unit 4: Lagrangian Formulation of Dynamics-II**

Lagrange's equations for velocity dependent potential, Lagrange's multiplier for holonomic and nonholonomic systems

**Unit 5: Hamiltonian Formulation Dynamics**

Generalized momentum and Cyclic coordinates, Conservation theorems, Hamiltonian Equations, Hamiltonian equations in different coordinate system, Examples in Hamiltonian Dynamics

**Unit 6: Two-Body Central Force Problem**

Central Force and Motion in a Plane, Equations of motion under central force and first integral, Differential equation for an orbit, Inverse square law of force, Kepler's laws of planetary motion and their deduction

**Unit 7: Variational Principle**

Euler's equation of calculus of variation, Euler-Lagrange's principle, Deduction of Hamiltonian's principle from D'Alembert's principle, Modified Hamiltonian's principle, Principle of least action

**Unit 8: Canonical Transformation**

Canonical transformation, Legendre's transformation, Generating Functions, Condition for canonical transformation

**Unit 9: Brackets and Liouville's theorem**

Poisson's Brackets, Lagrange's Brackets, Relation between Lagrange and Poisson Brackets, Angular momentum and Poisson Brackets, Liouville's Theorem

**Unit 10: Hamiltonian -Jacobi Theory**

The Hamiltonian-Jacobi equation, Solution of Harmonic oscillator problem by Hamilton -Jacobi method, Hamilton-Jacobi equation: Hamiltonian Characteristic Function, Kepler's problem: Solution by Hamiltonian's-Jacobi method

**Unit 11: Small Oscillations**

Potential energy and Equilibrium-One dimensional oscillator, Two coupled Oscillators, General theory of small oscillations

**Unit 12: Dynamics of a Rigid Body-I**

Generalized coordinates of a Rigid body, Body and space reference systems, Components of Angular velocity

**Unit 13: Dynamics of a Rigid Body-II**

Angular momentum and Inertia tensor, Principle axes -principle moments of Inertia, Rotational kinetic energy of a rigid body

**Unit 14: Noninertial and Rotating coordinate system**

Noninertial Frames of references, Fictitious or Pseudo Force, Centrifugal Force, Uniform Rotating Frames, Free fall of a body on Earth's surface

***Suggested Readings:***

1. Rao, K. Sankara. 2009. *Classical Mechanics*. New Delhi: PHI Learning Private Limited.
2. Upadhyaya, J.C. 2010. *Classical Mechanics*, 2nd Edition. New Delhi: Himalaya Publishing House.
3. Goldstein, Herbert. 2011. *Classical Mechanics*, 3rd Edition. New Delhi: Pearson Education India.
4. Gupta, S.L. 1970. *Classical Mechanics*. New Delhi: Meenakshi Prakashan
5. Takwala, R.G. and P.S. Puranik. 1980. New Delhi: Tata McGraw Hill Publishing.
6. Goldstein, H., Safko, J. and Poole, *Classical Mechanics*, 3<sup>rd</sup> Edition, 2001.
7. Rana, N.C. and Joag, P.S. *Classical Mechanics*, Tata McGraw-Hill, 2001.

## SEMESTER III: Integral Equations and Calculus of Variation

Course Type:	DSC
Number of Credits:	4
Total Marks:	100 (I.A:30, E.S.E: 70)

Course Objectives: The course will enable the learners to

- make the learner familiarize with resolvent kernel, successive approximation, solution of homogeneous Fredholm integral equation for solving integral equations and variational problems.

Course Learning Outcomes: After successful completion of this course, the learner will be able to

- Use the concept of different kernels and techniques for solving various kinds of integral equations.
- Find the solutions of Volterra integral equations using Neumann series method.
- Understand the relation between differential and integral equations.
- Learn about the formulation of variational problems, the variation of a functional and its properties, extremum of functional, sufficient condition for an extremum.

### Unit 1: Fredholm Integral Equations

Fredholm integral equation of first kind, Fredholm integral equation of the second kind, Fredholm integral equation of third kind, Homogeneous Fredholm integral equation

### Unit 2: Volterra Integral equations

Volterra integral equation of the first kind, Volterra integral equation of the third kind, Volterra integral equation of the second kind, Homogeneous Volterra integral equation

### Unit 3: Special types of kernels

Symmetric kernel, Separable kernel, Iterated kernel, Resolvent kernel, Eigenvalues (or characteristic values or characteristic numbers), Eigenfunctions, Leibnitz's rule of differentiation under integral sign

### Unit 4: Conversion of ordinary differential equations into integral equations

Initial value problem, Method of converting an initial value problem into a Volterra integral equation, Boundary value problem, Method of converting a boundary value problem into a Fredholm integral equation

### Unit 5: Homogeneous Fredholm Integral equations of the second kind with separable (or Degenerate) kernels

Characteristic values (or Characteristic numbers or eigenvalues), Characteristic functions (or eigenfunctions), Solution of homogeneous Fredholm integral equation of the second kind with separable (or degenerate) kernels

### Unit 6: Fredholm Integral equations of the second kind with separable (or Degenerate) kernels

Solution of Fredholm integral equations of the second kind with separable (or degenerate) kernels, Fredholm theorem, An approximate method

**Unit 7: Method of Successive Approximations**

Iterated kernels or functions, Resolvent (or reciprocal) kernels, Solution of Fredholm integral equation of the second kind by successive approximations, Solutions of Volterra integral equation integral equation of the second kind by successive substitutions, Iterative method (Iterative scheme), Neumann series, Solution of Volterra integral equation of the second kind by successive approximations, Solution of Volterra integral equation of the second kind when its kernel is of some particular forms, Solution of Volterra integral equation of the second kind by reducing to differential equation

**Unit 8: Integral equations with symmetric kernels**

Symmetric kernels, Regularity conditions, the inner product or scalar product of two functions, Solution of the Fredholm integral equation of the first kind with symmetric kernel

**Unit 9: Singular Integral equations**

Singular integral equation, The solution of the Abel integral equation, General form of the Abel singular integral equation

**Unit 10: Variational problems with fixed boundaries**

Functionals, Euler's equation, Another form of Euler's equation, Particular case of Euler's equation, Necessary condition of extremum, Sufficient condition for extremums, Functionals dependent on higher-order derivatives, Extension of the variational case: several dependent variables, Isoperimetric problems, Lagrange's equation

**Unit 11: Variational problems with moving boundaries**

Transversality Conditions, Variational problems with moving boundary in implicit form, Basic problems with variable end

**Unit 12: Sufficient Conditions for an Extremum**

General definitions, Jacobi condition, Weirstrass function, Sufficient condition for extremum: Legendre condition, Application of the Calculus of variation, Principle of least action, Lagrange's equation from Hamilton's principle

**Unit 13: Canonical transformations**

Canonical or contact transformation, Conditions for a transformation to be canonical

**Unit 14: Direct Methods**

Direct methods in variational problems, Ritz Method, Galerkin's Method, Collocation method

***Suggested Readings:***

1. Wazwaz, A. M. *A First Course in Integral Equations*. 2nd edition World Scientific Publishing Co. 2015.
2. Kanwal, R. P. *Linear Integral Equation. Theory and Techniques*. Academic Press, 2014.

3. Gelfand, I. M. and Fomin, S. V. *Calculus of Variations*. Courier Corporation, 2012.
4. Hildebrand, F. B. *Method of Applied Mathematics*, Courier Corporation, 2012.
5. Raisinghania M. D. *Integral Equation & Boundary Value Problem*. S. Chand Publishing, 2007.
6. Jerri, A. *Introduction to Integral Equations with Applications*, John Wiley & Sons, 1999.
7. A.S. Gupta: *Calculus of Variation with applications*, PHI, 1999.

## SEMESTER IV: Numerical Analysis and Computation

Course Type:	<b>DSC</b>
Number of Credits:	<b>4</b>
Total Marks:	<b>100 (I.A:30, E.S.E: 70)</b>

Course Objectives: The course will enable the learners to

- introduce the basic of systems of linear algebraic equations and their solutions, error analysis, rate of convergence, eigen value problem, solving ordinary differential equations, Finite difference methods for 2D and 3D elliptic boundary value problems.

Course Learning Outcomes: This course will enable the students to:

- Apply Iterative method for matrix inversion.
- Solving of eigen value problem by Jacobi's method, Given's method, Power method.
- Apply Euler's method, Single step Methods, Taylor series method, Runge-Kutta's method to solve ordinary differential equations.
- Apply numerical techniques to obtain approximate solutions to otherwise intractable mathematical problems
- Learn numerical technique to find the solutions of nonlinear equations, system of linear equations, interpolation problems, numerical differentiations and integration, Initial and boundary value problems

### Unit -1: Error Analysis and Numerical Computations

Approximate numbers and significant figures, Rounding of numbers, Errors, A general formula for errors, Accuracy in the evaluation of a formula, Computer representation of numbers, Floating point Arithmetic, Propagation of errors, Loss of significant digits, propagation of error in function evaluation

### Unit-2: Interpolation

Lagrange and Newton Interpolation, Lagrange Interpolation, Newton divided difference Interpolation, Gregory-Newton backward, Central interpolation, Hermite Interpolation

### Unit -3: Spline Interpolation

Quadratic Spline Interpolation, Cubic Spline Interpolation

### Unit -4: Solution of transcendental and polynomial equations

Solution of equation, Iterative methods and related concepts, Bisection method, The method of iteration, Regula-Falsi method, Secant method, Newton-Raphson method, Roots of a polynomial

### Unit 5: Interpolation (With equal Intervals)

Newton's forward interpolation, Backward Interpolation formula, Central-difference interpolation

**Unit 6: Interpolation (With unequal Intervals)**

Lagrange's interpolation formula, Divided difference, Hermite's interpolation formula

**Unit 6: The Accuracy of Interpolation Formulas**

Error of polynomial approximation, Remainder term in Newton's forward interpolation formula and in Lagrange's formula, Remainder term in Newton's backward formula, Remainder term in Stirling's formula

**Unit 7: Numerical Differentiation**

Numerical differentiation, Derivatives of the functions at the given arguments unequally spaced

**Unit 8: Numerical Integrations**

Numerical Quadrature, Quadrature formula for equally spaced arguments, The trapezoidal rule, Simpson's  $\frac{1}{3}$  rule, Simpson's  $\frac{3}{8}$  rule, Newton-Cote's formula

**Unit 10: Numerical Solution of Ordinary Differential Equations**

Picard's method, Taylor's series method, Euler's method, Modified Euler's method, Runge-Kutta method, Predictor-Corrector methods, Adams-Bashforth method

**Unit 11: Solution of Simultaneous Algebraic Equations**

Systems of simultaneous linear equations, Gauss elimination method, LU decomposition method, Jordan's method, Iterative methods: Jacobi method, Gauss-Seidel method, Ill-conditioned system of equations

**Unit 12: Numerical Solution of Partial Differential Equation**

Finite-difference approximations to partial derivative, Solution to Laplace equation, One dimensional heat equation, One dimensional heat equation, Solution of wave equation

**Unit 13: Numerical Algorithm in C-I**

Computer codes: Bisection method, Regula-falsi method, Secant method, Newton-Raphson method, Newton forward method, Newton's Backward method

**Unit 14: Numerical Algorithm in C-II**

Trapezoidal method, Simpson's method, Gauss elimination method, Gauss-Jordan method, Gauss-Seidel method, Jacobi's method

**Suggested Readings:**

1. Gupta, R. K. *Numerical Methods: Fundamentals and Applications*. 1st edition, Cambridge University Press, 2019.
2. Thangaraj, P. *Computer Oriented Numerical Methods*. PHI Learning Pvt. Ltd, 2013.
3. Jain, M. K., Iyengar, S. R. K. and Jain, R. K. *Numerical Methods for Scientific & Engineering Computation*. New Age International, 2012.
4. Burden R. L. and Faires J. D. *Numerical Analysis*. 9th Edition, Cengage Learning, 2011.
5. Chapra, S. C. and Canale, R. P. *Numerical Methods for Engineers*. McGraw Hill, International Edition, 1998.



6. Mathews, J. H. *Numerical Methods for Mathematics, Science and Engineering*. Prentice-Hall, International Editions, 1992.

## SEMESTER IV: Number Theory

Course Type:	<b>DSC</b>
Number of Credits:	<b>4</b>
Total Marks:	<b>100 (I.A:30, E.S.E: 70)</b>

### Course Objectives:

The primary objective of this course is to

- Understand the basic concepts of Number theory like congruence and divisibility and their application. They will have the knowledge of famous theorem like Fermat's and Chinese Remainder theorem and their application to other field of science.
- solve the day-to-day problems by using Fibonacci sequence and Pell's equation.
- Course Learning Outcomes: This course will enable the students to:
- Understand the properties of divisibility and prime numbers, compute the greatest common divisor and least common multiples and handle linear Diophantine equations
- Use the operations with congruence's, linear and non-linear congruence equations
- Apply the theorems: Chinese Remainder Theorem, Lagrange theorem, Fermat's theorem, Wilson's theorem

### Unit 1: Basic Concepts

Division algorithm, Greatest common divisor, Euclidean algorithm, least common multiple, Kronecker's theorem

### Unit 2: Divisibility Theory

Divisibility, Tests of divisibility

**Unit 3: Primes and their distribution**

Prime numbers, Fundamental theorem of arithmetic

**Unit 4: Theory of Congruence-I**

Congruence, Basic properties of congruence, Residue system, Linear congruence

**Unit 5: Theory of Congruence-II**

Solvability condition of a system of linear congruence, The linear Diophantine theorem, The Chinese Remainder Theorem

**Unit 6: Fermat's Theorem**

Fermat's factorization method, Fermat's little theorem, Wilson's theorem, Euler's factorization method

**Unit 7: Number Theoretic Functions-I**

The function  $\tau$  and  $\sigma$ , The mobius function, The greatest integer function, Euler's function, Some properties of Euler's function

**Unit 8: Number Theoretic Functions-II**

Function  $T(n)$ ,  $S(n)$ ,  $\zeta(n)$ ,  $\phi(n)$

**Unit 9: Primitive roots and indices**

The order of an integer modulo  $n$ , Primitive roots, Primitive roots for primes, Composite numbers having primitive roots, The theory of indices

**Unit 10: Quadratic Congruence and Quadratic Reciprocity law**

Quadratic congruence, Quadratic residue, Euler's residue, Legendre symbol and its properties, Quadratic reciprocity, Quadratic congruences with composite module, Jacobi symbol

**Unit 11: Perfect Numbers**

Perfect numbers, Mersenne primes, Fermat number, Pythagorean triples, Other Diophantine equation, Fermat's last theorem

**Unit 12: Sum of square of Integers**

Sum of two square, Sum of more than two squares

**Unit 13: Partitions**

Introduction, Graphical Representation, Euler's Partition Theorem, Searching for Partition Identities

**Unit 14: Farey Sequences and Continued Fractions**

Farey Sequence, Continued Fractions, Finite Continued Fractions, Infinite Continued Fractions, Application to Equations, Pell's Equation, Fibonacci Numbers, Fibonacci Sequence, Certain Identities involving Fibonacci Numbers

**Suggested Readings:**

1. David Burton: Elementary Number Theory, Universal Book Stall, New Delhi
2. George E. Andrews: Number Theory, Hindustan Publishing Corporation, New Delhi
3. K.C. Chowdhury: A First Course in Theory of Numbers, Asian Books Pvt. Ltd.,
4. RamanujacharyKumanduri; Cristina Romero: Number Theory with Computer Applications, Prentice Hall, New Jersey
5. G.H. Hardy; E.M. Wright: An Introduction to the Theory of Numbers, OUP.
6. Thomas Koshy: Elementary Number Theory with Applications, Harcourt Science and Technology Company.
7. S.G. Telang (eds. M.G.Nadkarni&J.S.Dani) : Number Theory, Tata McGraw-Hill Publishing Company Limited
8. Gareth A. Jones & J. Mary Jones, Elementary Number Theory, Springer
9. Apostol, T. M. Introduction to Analytic Number Theory. Springer 2014.
10. Niven, I. and Zuckerman, H. S. Introduction to the Theory of Numbers. John Wiley & Sons, 2008.

11. Hardy, G. H. and Wright, E. M. Theory of Numbers. Oxford Science Publications, 2003.

## **SEMESTER IV: Graph Theory**

Course Type: DSC

Number of Credits:4

Total Marks: 100 (I.A:30, E.S.E: 70)

### **Course Objectives:**

The course will enable the learners to

- introduce the concept of undirected graph, operation and connectedness of graph, different types of graphs, tree, center and centroid, independent cycles and co cycles, Connectivity and traversability, planarity and colorability,

### **Course Learning Outcomes:**

This course will enable the students to:

- Learn and apply the connectedness of graph
- Learn and apply the different types of operations of graph
- Understand tree and its significance and applications in graph theory
- Have the knowledge of point connectivity and line connectivity and their applications
- Applications of Eulerian and Hamiltonian graph
- Learn and apply the Kuratowski's theorem in planar graph
- Learn and apply the point coloring and chromatic number

### **Unit 1: Introduction to Graph theory**

The Konigsberg Bridge problem, Graph: Definition, the degree of a vertex, Isomorphism of graphs, Directed graph or Digraph

### **Unit 2: Graph Operations**

Union of two graphs, Edge and Vertex, Joint of two graphs, Product of two graphs, Homeomorphism of Graphs, Intersection Graphs

### **Unit 3: Bipartite Graphs**

Characterizations of bipartite graphs, Cayley's Formula

**Unit 4: Connectivity**

Walk, Path, Cycle in a graph, Edge and Vertex connectivity

**Unit 5: k-Connected graphs**

2-connected graphs, k-Connected and k-edge Connected graphs

**Unit 6: Tree**

Definition, Properties of Trees, Center and Centroid of Tree, Independent Cycles and Co-cycles, Block cut point tree

**Unit 7: Cut-Sets and Cut-Vertices**

Cut-sets, some properties of Cut-sets, Cut-vertices, Fundamental circuits and cut-sets

**Unit 8: Bridges and Algorithm**

Bridges, Breadth-first algorithm, Depth-first algorithm, Prim's and Kruskal algorithm, Dijkstra's algorithm

**Unit 9: Traversability**

Eulerian Graphs, Hamiltonian Graph, The Shortest path problem, The Chinese Postman problem, The Travelling Salesman Problem

**Unit 10: Matching and Coverings**

Matchings, Coverings, Dominating Sets and Domination numbers, Factorization, Critical Vertices and Edges

**Unit 11: Colorability**

Vertex Coloring, Chromatic Polynomial, Edge Coloring

**Unit 12: Planarity**

Planar graph, Kuratowski's Theorem, Outerplanar Graph, The five Color problem, Dual graphs

**Unit 13: Matrices: associated with graphs**

Adjacency Matrix, The Incidence Matrix, Cycle Matrix, Path Matrix and Cut-set Matrix

**Unit 14: Digraphs**

Digraph, Directional Duality and Acyclic Digraph, Matrices associated with Digraphs

**Suggested Readings:**

1. F. Harary, Graph theory, Narosa Publishing House, New Delhi, 1988.
2. R. Balakrishnan and K. Renganathan, A textbook of Graph theory, Springer, 2000
3. B. Bollobas, Modern Graph Theory, Springer, 2002
4. G. Chartrand, L. Lesniak, Graphs & digraphs (Fourth edition), Chapman & Hall/CRC, 2005.
5. R. J. Wilson, Introduction to Graph Theory (5th Edition), Prentice Hall, 2010

# Master of Science (Mathematics) DETAILED COURSE WISE SYLLABUS

## Syllabus of Discipline Specific Elective (DSE) Courses

### **SEMESTER I: Computer Programmimg using C**

Course Type: DSE

Number of Credits:4

Total Marks: 100 (I.A:30, E.S.E: 70)

#### **Course Objectives:**

The course will enable the learners to

- Develop proficiency in programmimg using the C language.
- Understand basic programmimg concepts such as data types, variables, control structures, functions, and arrays.
- Acquire skills to design and implement efficient algorithms and programmes using C language.
- Learn to use C programmimg to solve real-world problems and challenges.
- Course Outcomes: Course Outcomes: After successful completion of this course, the learner will able
- write and debug C programmes using programmimg constructs like variables, data types, control structures, functions, arrays, and pointers.
- design and implement programmes that meet specific requirements using C programmimg techniques, algorithms, and data structures.
- apply their skills to a wide range of real-world problems. This includes the ability to analyze a problem, break it down into smaller parts, and develop a solution using



programmemeingconcepts.

**Unit 1: Introductory Concepts**

Basic definition of Pseudo Code, algorithm, flowchart, programme

**Unit 2: Elements of C Programmemeing**

Characters used in C, Identifiers, Keywords, Tokens, Constants, Variables, Types of Cvariables, Receiving input and output

**Unit 3: Variables and Data types**

Integer, character floating point and string; Initialization of variable during declarations; Symbolic Constants, type conversion in assignment

**Unit 4: Operators and Expressions**

Expression in C, Different types of operators: Arithmetic, Relational and Logical, Assignment, Conditional, Increment and decrement, Bitwise, Comma and other operator (size of, periodetc). Precedence and associativity of operators, type casting

**Unit 5: I/O Functions**

Header Files (stdio, conio), Formatted Input/Output Functions (scanf, printf), EscapeSequences, Character Input/Output Functions (getch, getchar, putchar, gets, puts, getche, clrscr)

**Unit 6: Preprocessor Directives** Features of C preprocessor, Macro expansion, Macros with arguments, #if and #elif Directives

**Unit 7: Conditional Statements**

Conditional Statement- if, if- else, nested if-else, switch-case; break, continue, goto

**Unit 8: Loop Control Structures**

Concept of Loops, Types of loops: while, do-while, for; nested loops

**Unit 9: Storage Class**

Automatic, External, Static, Register, Scope and lifetime of variables, Macro, Preprocessor Directive

**Unit 10: Arrays**

Array, Array Declaration, 1-Dimensional array, 2-Dimensional array

**Unit 11: Strings**

String, String Handling Functions: strlen(), strcmp(), strcpy(), strrev(), strcat(), etc

**Unit 12: Functions**

Function, Function declaration, Function definition, Function call, Formal and Actualparameter, Recursive function

**Unit 13: Pointers**

Pointer, Pointer declaration, Passing pointer to a function, Pointer and one-dimensional arrays, Dynamic memory allocation

**Unit 14: Structures and Union**

Structure Declarations, Definitions, Defining your typedef, Array of Structure, Pointer to Structure. Union Declaration, Definition, Declaration, Uses

**Unit 15: File Handling**

Concept of File, File Pointer, File Opening in various modes, closing a file, reading and writing on files, Formatted Input/Output, fseek(), ftell(), rewind()

**Suggested Readings:**

1. Kanetkar, Y. (2018). Let Us C (16th ed.). Delhi: BPB Publications.
2. Balaguruswamy, E. (2019). Programmemeing in ANSI C (7th ed.). Delhi: Tata McGraw-Hill Education Private Limited

## **SEMESTER II: Operations Research**

Course Type: DSE

Number of Credits:4

Total Marks: 100 (I.A:30, E.S.E: 70)

### **Course Objectives:**

The course will enable the learners to

- Formulate and model a linear programming problem from a word problem and solve them graphically in 2 and 3 dimensions.
- Formulate and solve a number of problems in game theory using various methods.

### **Course Outcomes:**

After successful completion of this course, the learner will able

- Understand the concept of operations research methods and its uses in various fields.
- Learn about the graphical solution of linear programming problem with two variables.
- Learn about the relation between basic feasible solutions and extreme points.
- Understand the theory of the simplex method used to solve linear programming problems.
- Learn about the relationships between the primal and dual problems
- Solve transportation and assignment problems

### **UNIT 1: Introduction to operations research**

Historical Background, Scope of Operations Research, Features of Operations Research, Phases of Operations Research, Types of Operations Research Model, Operations Research Techniques and Tools, General Methods for Solving Operations Research Model, Limitations of Operations Research

**UNIT 2: Linear programming problem (LPP)**

Linear programming problem (LPP), General form of Linear programming problem (LPP), Some important definitions, Basic assumption of LPP, Application of LPP, Limitations of LPP, Mathematical formulation of LPP

**UNIT 3: Graphical method of solution for LPP**

Some basic definition, Graphical methods to solve LPP, Some special cases, Limitations of graphical method

**UNIT 4: Simplex Method**

Standard Form of Linear Programming Problem (LPP), General LPP, Canonical and Standard Forms of LPP, Solution of LPP, Fundamental Theorem of LPP, the Simplex Algorithm, Big-M Method, Two-Phase Method

**UNIT 5: Duality in Linear programming problem**

Importance of Duality Concepts, Formulation of Dual Problem, Economic Interpretation of Duality, Sensitivity Analysis

**UNIT 6: Transportation Problem**

Formulation of Transportation Problem (TP), Basic Theorems on TP, Initial Basic Feasible Solution: North-West Corner Method, Matrix-Minima Method, Vogel Approximation Method, Optimality Test, Algorithm of MODI Method

**UNIT 7: Assignment problem**

Formulation of an Assignment Problem, Assignment Problem as a Special Case of Transportation Problem, Solution of an Assignment Problem, The Hungarian Method of Solution of an Assignment Problem, The Travelling Salesman Problem (Shortest Cyclic Route Model)

**UNIT 8: Game theory**

Competitive Situations, Characteristics of Competitive Games, Two-Person Game, Two-Person Zero-Sum Game, Pay-off Matrix, Strategy,

Maximin and Minimax Principle, Saddle Point, Value of a Game, and Symmetric Game, Dominance Property

**Unit 9: Introduction to project Management**

Meaning and Features of Project, Meaning of Project Management, Need of Project Management, Life Cycle of a Project, Life Cycle Curve

**Unit 10: Project Planning**

Project Planning, Planning of Physical, Human and Financial Resources

**Unit 11: Project Scheduling and PERT, CPM**

Project, Project planning, Project Scheduling Network and its basic components, Procedure relationship, CPM, PERT, Basic difference between PERT and CPM

**UNIT 12: Project completion and Evaluation**

Integrated Power Management Control System, Project Management, Transition, Project Completion and Evaluation, Project Review and Termination

**Unit 13: Sequencing**

Definition and examples, Johnson's algorithm, Three machine problem, Processing of two jobs on 'n' machines

**Unit 14: Non-linear Programmemeing**

Formulation of a non-linear programmemeing problem (NLPP), General non-linear programmemeing problem, Constrained optimization with equality constraints, Constrained optimization with inequality constaints, Saddle point problems, Saddle points and NLPP

**Suggested Readings:**

1. Operations Research: Prem Kuman Gupta, D. S. Hira :S. Chand &Company Ltd.
2. Operations Research: Kanti Swarup, P. K. Gupta, Man Mohan (Sultan Chand and Sons)

3. Panneerselvam: Operations Research (2006), Prentice Hall of India Private Limited, New Delhi.
4. Sharma, S. D. Operation Research, Kedar Nath Ram Nath Publications, 2012.
5. Swarup, K. and Gupta, P.K. Operations Research. S. Chand publisher, 2010.
6. Taha, H. A. Operation Research: An Introduction.9th edition, Pearson, 2010.
7. Gupta, P.K. and Hira, D.S. Introduction to Operations Research, S. Chand & Co. 2008.
8. Sharma, J. K., Mathematical Model in Operation Research, Tata McGraw Hill, 1989.

## **SEMESTER III: Measure theory and Integration**

Course Type: DSE

Number of Credits:4

Total Marks: 100 (I.A:30, E.S.E: 70)

### **Course Objectives:**

The course will enable the learners to

- Understand and apply the Lebesgue measure in determining lengths of intervals, open and closed sets, and the concept of Lebesgue measurable sets including Borel sets
- Understand the definitions and properties of outer measure, measurable sets, and regularity of measures
- Compute Lebesgue integrals for bounded and unbounded functions over intervals and subsets of real numbers and understand theorems related to general Lebesgue integrals

### **Course Outcomes:**

After successful completion of this course, the learner will be able

- Calculate Lebesgue measures for intervals, open and closed sets, and determine Lebesgue measurable sets and Borel sets
- Calculate outer measures and identify measurable sets
- Compute Lebesgue integrals for bounded and unbounded functions, apply theorems related to general Lebesgue integrals
- Apply the concepts of signed measures, decomposition theorems, absolute continuity and the Radon-Nikodym theorem

### **Unit 1: Countability of Sets and Cardinal Numbers**

Countable set, Algebraic numbers, Cardinal number of a set, Transcendental numbers

**Unit 2: Open sets and Closed sets on the real line**

Intervals, Open sets, closed sets

**Unit 3: Lebesgue Measure in the real line**

Length of intervals, Lengths of open and closed sets, Lebesgue inner measure, Lebesgue measurable set, Borel sets and their measurability

**Unit 4: Outer Measure and Measurability**

Definitions, Ideal measure function, Measurable set, Regularity of measure

**Unit 5: Measurable Functions**

Definitions, Borel measurable functions

**Unit 6: The Lebesgue Integral of a Function-I**

Lebesgue integral of bounded function on Interval  $[a,b]$ , Lebesgue integral for bounded functions over a subset of real numbers

**Unit 7: The Lebesgue Integral of a Function-II**

General Lebesgue integral for unbounded functions, Integral of non-negative function, Theorem on general Lebesgue Integrals

**Unit 8: Convergence of Sequence of Measurable Functions**

Convergence almost everywhere, Pointwise convergence, Convergence in measure, Uniform convergence almost everywhere, Little wood's three principle

**Unit 9: Differentiation and Integration**

Absolute Continuous functions, Monotone functions, Functions of bounded variation, Vitali's lemma, Indefinite integral, Four Dini's derivatives

**Unit 10:  $L^p$  Spaces**

$L^p$  space, Norm of an element of  $L^p$ -Space, Riesz-Holder inequality, Schwarz or Cauchy -Schwarz inequality, Minkowski's or Riesz-Minkowski's inequality, Properties of  $L^p$  Spaces,  $L^p$  Spaces for  $p=\infty$



**Unit 11: Signed Measure**

Definition: Signed measure, Positive, Negative and Null sets, Hahn decomposition theorem, Jordan decomposition, singular measure, Absolutely continuous measure function, Radon-Nikodym theorem

**Unit 12: Product Measure**

Product of two sets, Rectangle, Sections, Product measure, Double integral, Iterated integrals, Fubini's theorem

**Unit 13: Measurable functions and their Integrals**

Measurability relative to a basic ring, Topology of sequential convergence, Fundamental existence theorem

**Unit 14: Extension of the Lebesgue Integral**

Uniqueness theorem, General Denjoy Integral

**Suggested Readings:**

1. Lawrence C. Evans and Ronald F. Gariepy, Measure Theory and Fine Properties of Functions. CRC Press, Taylor & Francis Group, 2015
2. Donald L. Cohn: Measure Theory, Springer, 2013.
3. Terence Tao: An Introduction to Measure Theory, American Mathematical Society (AMS), 2011
4. Sheldon Axler: Measure, Integration & Real Analysis, Springer's Graduate Texts in Mathematics series, 2020.
5. Robert G. Bartle: A modern theory of integration, Graduate Studies in Mathematics. MS, vol 32 2001.

## SEMESTER III: Fluid Dynamics

Course Type: DSE

Number of Credits:4

Total Marks: 100 (I.A:30, E.S.E: 70)

Course Objectives:

The course will enable the learners to

- Prepare a foundation to understand the motion of fluid and develop concept, models and techniques which enables to solve the problems of fluid flow and help in advanced studies and research in the broad area of fluid motion.
- provide a treatment of topics in fluid dynamics to a standard where the student will be able to apply the techniques used in deriving a range of important results and in research problems.
- provide the student with knowledge of the fundamentals of fluid dynamics and an appreciation of their application to real world problems.

**Course Outcomes:**

After successful completion of this course, the learner will able

- Use the concept of stress in fluids with applications.
- Analyse Irrotational and rotational flows in fluids and some of their properties
- formulate mass and momentum conservation principle and obtain solution for nonviscous flow.
- understand the concept of stress and strain in viscous flow and to derive Navier-Stokes equation of motion and solve some exactly solvable problems.
- derive the path-lines and the streamlines in Cartesian and polar form from a velocity field
- derive the stream function from a velocity field
- understand how the equations of continuity is derived

(conservation of mass) and its consequences about compressibility.

- understand how Euler's equation is derived, what it represents, and use it to find the pressure distribution from a velocity and deduce Bernoulli's equation.
- understand how Navier-Stoke's Equation (Consideration of viscosity) is derived some exact solutions of Navier-Stoke's Equation model different flows from a combination of uniform flows, sources, sinks and doublets

### **Unit-1: Introduction**

Some basic properties of fluid, Viscous and inviscid fluids, Viscosity, Newtonian and non-Newtonian fluids, Real and ideal fluids, Some important types of flows

### **Unit-2: Kinematics of fluids in motion**

Methods of describing fluid motion, Lagrangian method, Eulerian method, Velocity of a fluid particle, Acceleration of a fluid particle, Stream line, Path line, Streak line, Velocity potential

### **Unit-3: Equation of Continuity**

The equation of continuity (or equation of conservation of mass) by Euler's method, the equation of continuity in cartesian coordinates, the equation of continuity in cylindrical coordinates, the equation of continuity in spherical polar coordinates, Equation of continuity in generalized orthogonal curvilinear coordinates, The equation of continuity by the Lagrangian method.

### **Unit-4: Equation of Motion of inviscid flows**

Euler's equation of motion, The equation of motion of an inviscid fluid, Conservative field of force, Euler's equation of motion in cylindrical coordinates, Euler's equation of motion in Spherical coordinates, The energy equation

**Unit-5: One-dimensional inviscid incompressible flow**

Integration of Euler's equation of motion, Bernoulli's equation, Pressure equation, Bernoulli's theorem

**Unit-6: Motion in two dimensions (Sources & Sinks)**

Motion in two-dimension, Stream function or current function, Physical significance of stream function, Irrotational motion in two-dimensions, Complex potential, Sources and Sinks, Sources and Sinks in two dimensions

**Unit-7: General theory of irrotational motion**

Connectivity, Flow and circulation, Stokes's theorem, Kelvin's circulation theorem, Green's theorem, Kelvin's minimum energy problem

**Unit-8: Motion of Cylinders**

Boundary conditions for stream function, General motion of cylinder, Kinetic energy of liquid

**Unit-9: Motion of a Sphere (Motion in three dimension)**

Equation of continuity, Liquid streaming past a fixed sphere, Equation of a sphere

**Unit-10: Stokes's Stream function**

Stoke's function, Property of Stoke's function, Irrotational motion, Solution for  $\psi$ , Motion of a solid of revolution along the axis, Motion of liquid inside a rotating ellipsoid sphere, Motion of an ellipsoid in an infinite mass of a liquid

**Unit-11: Vortex Motion**

Vorticity, Vorticity components, Vortex line, Vortex tube and vortex filaments, Helmholtz's vorticity theorems, Properties of vortex tube, Two vortex filaments, Motion of any vortex, Kirchhoff vortex theorem

**Unit-12: Waves**

General expression of a wave motion, Mathematical expression of wave motion, Standing or stationary motion, Types of liquid waves, Surface

waves, The energy of progressive waves, The energy of stationary waves, Capillary waves or Ripples

**Unit-13: Viscosity**

Most general motion of a fluid element, Strain tensor, Strain Analysis, Stress Analysis, Newtonian and non-newtonian fluids. Principal stresses and Stoke's relation

**Unit-14: The Navier-Stokes Equations and the energy equation**

The Navier-Stokes equation of motion of a viscous fluid, some exact solutions of Navier-Stokes equation

**Unit-15: Boundary Layer Flow**

Prandtl's boundary layer theory, Boundary layer equations, Prandtl's number, Euler's number, Froude number, Weber number, Mach number, Eckert number

**Suggested Readings:**

1. Besaint, W.H. and Ramsey, A.S. A Treatise on Hydromechanics Part I hydrostatics, Andesite Press, 2017.
2. Kundu, P.K., Cohen, I. M. and Dowling, R. D. Fluid Mechanics, 6th edition, Academic Press, 2015.
3. O'Neil, M. E., and Chorlton, F. Ideal and Incompressible Fluid Dynamics. Ellis Horwood Ltd, 1986.
4. Yuan, S.W. Foundations of Fluid Mechanics. Prentice Hall of India Private Limited, New Delhi, 1976.
5. Curle, N. and Davies, H. J. Modern Fluid Dynamics. Vol1, D Van Nostrand Company Ltd, London, 1968.
6. Raisinghania, M. D. Fluid Dynamics. S. Chand & Company Ltd., New Delhi, 2001

## SEMESTER IV: Differential Geometry

Course Type: DSE

Number of Credits:4

Total Marks: 100 (I.A:30, E.S.E: 70)

### Course Objectives:

The course will enable the learners to

- understand several concepts of Differential Geometry such as space curves, surfaces, curvatures, torsion, developable and geodesics.

### Course Outcomes:

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

- Learn about the concepts of curvature, torsion, involutes and evolutes.
- Familiarize with several concepts of tangent plane, Helicoids, metric and direction coefficients.
- Understand the concepts of developable surfaces.
- Use the several notions of curvatures such as geodesic curvature and Gaussian curvatures.

### Unit 1: Tensor Algebra

Contravariant and Covariant vector, Definition of tensor, Gradient, Tensor field, Addition and subtraction of tensors, Multiplication of tensors, Inner product, Contraction, Symmetric tensor, Antisymmetric tensor, Quadratic law, Reciprocal tensor

### Unit 2: Riemannian metric

Metric,  $g_{ij}$  is a second rank covariant symmetric tensor, Length of a curve, Magnitude of a vector, Unit tangent vector, Associate vectors, Scalar product, Projection of a vector along a direction, Gradient of a scalar function, Angle between two vectors, Angle between co-ordinate curves, Hypersurface, Angle between coordinate hypersurface

**Unit 3: Christoffel symbols covariant differentiation**

Christoffel symbols, Tensor laws of transformation of Christoffel symbols, Covariant derivative of a covariant vector, Covariant derivative of a covariant second rank tensor, Covariant derivative of a scalar, Divergence of vector, Covariant constant, Curl

**Unit 4: Curves in Space-I**

Space curve, Class or Function of a Curve, Tangent, Tangent line at a point on a space curve, Order of contact between curves and surfaces, Arc length, Osculating plane, Normal lines and Normal Plane, Rectifying Plane, Fundamental Planes, Equation of the principal normal and Binormal, Curvature, Torsion, Screw Curvature, Serret Frenet formulae, Curvature and Torsion of any curve  $r=r(t)$

**Unit 5: Curves in Space-II**

Direction cosines of the principal normal and Binormal, Curvature and Torsion of a Curve given by the intersection of two surfaces, Cylindrical Helices, Circular Helix, Intrinsic Equations, Fundamental Theorems for Space curves, Osculating Circle (or the circle of curvature), the osculating sphere (or the sphere of curvature)

**Unit 6: Involute and Evolute**

Involute of a given space curve, Evolute of a give curve, Curvature and Torsion of the Evolute

**Unit 7: Concept of A Surface and Envelopes and developable**

Class of a surface, Regular (or Ordinary) point and singularities on a surface, Transformation of parameter, Geometrical transformation of proper transformation, Curvilinear Equations of the curve on the surface, Parametric curve, Tangent plane and Normal, Family of surfaces

**Unit 8: Fundamental Forms and Curvature of surfaces**

First fundamental Form or Metric, Geometrical Interpretation of metric, An important relation between the coefficients  $E, F, G$  and

H, Important properties of the metric, Element of area, Angle between the parametric curves, Second fundamental form and second order magnitudes, Surface of revolution, Family of curves

**Unit 9: Local non-intrinsic properties of a Surface**

Normal curvature, Principal Directions, Minimal surface, Developable surface, Lines of curvature

**Unit 10: Conjugate and Asymptotic Lines**

Conjugate directions, Condition of conjugate, Principal property of conjugate directions

**Unit 11: Asymptotic Lines**

Asymptotic lines, Condition for asymptotic lines to be orthogonal, Asymptotic lines on a ruled surface, Formulae of curvature and torsion of an asymptotic line

**Unit 12: Fundamental Equations of Surface theory and parallel surfaces**

The Fundamental equation of surface theory, Parallel surfaces, Gaussian curvature and Mean curvature for the parallel surface

**Unit 13: Geodesics**

Geodesics, Canonical geodesic equations, Nature of geodesics on a surface of revolution, Normal property of geodesics, Differential equations of geodesics by using normal property, Torsion of geodesic, Geodesic tangent

**Unit 14: Geodesics Curvature**

Geodesic curvature, Formula for geodesic curvature, Geodesic parallels, Geodesics co-ordinate, Geodesic polar co-ordinates, Angle between a curve on a surface and a Geodesic through a pole, Geodesic mapping

**Suggested Readings:**

1. Weatherburn, C. E. Differential Geometry of Three Dimensions, Cambridge University Press, 2016.



2. Graustein, W. C. Differential Geometry. Courier Corporation, 2012.
3. Wilmore T. J. An Introduction to Differential Geometry, Dover Publications Inc., 2012.
4. Pressley, A. Elementary Differential Geometry. Springer, 2002.

## SEMESTER IV: Fuzzy Sets and Applications

Course Type: DSE

Number of Credits:4

Total Marks: 100 (I.A:30, E.S.E: 70)

### Course Objectives:

The course will enable the learners to

- introduce the fundamental concepts in fuzzy sets, fuzzy relations, arithmetic operations on fuzzy sets, probability theory, fuzzy logic and its applications

### Course Outcomes:

After successful completion of this course, the learner will able to

- Understand the basic concepts of t- norms, t- conforms and operation of
- Use the concepts of approximation of triangular fuzzy number, operations of trapezoidal fuzzy number, bell shape fuzzy number, crisp function and its applications.
- Analyse the Integration and differentiation of fuzzy function product set, and understand the basic concepts of composition of fuzzy relation, fuzzy graph, projection

### Unit 1: Fuzzy Set

Concepts of fuzzy set, Types of Fuzzy sets, Characteristic of Fuzzy sets, General properties

### Unit 2: Operations on Fuzzy Sets

Extension principle for Fuzzy sets, Fuzzy Compliments, fuzzy union, fuzzy intersection, other operations in fuzzy set, t-Norms and t-Conorms

### Unit 3: Fuzzy Numbers and Arithmetic

Fuzzy numbers, Algebraic operations with Fuzzy numbers, Binary operations of two Fuzzy numbers, Fuzzy arithmetic, Arithmetic

operations on Fuzzy numbers in the form

**Unit 4: Fuzzy Relations**

Projections and cylindrical Fuzzy relations, Composition, Properties of Min-Max composition, Binary relations on a single set, Compatibility relation, Fuzzy ordering relation

**Unit 5: Fuzzy Graph**

Fuzzy graph, Fuzzy Morphisms

**Unit 6: Possibility Theory**

Fuzzy measures, Evidence theory, Probability measure, Possibility and necessity measure, Possibility distribution as Fuzzy sets

**Unit 7: Approximate reasoning**

Fuzzy Implications, Axioms of Fuzzy Implications, Selection of Fuzzy Implications

**Unit 8: Fuzzy Logic**

Fuzzy logic and Fuzzy proposition, Fuzzy connectives, Fuzzy Inference, Fuzzy Propositions, Fuzzy Quantifiers, Linguistic Hedges, Inference from Conditional Fuzzy Propositions

**Unit 9: Fuzzy Systems and Fuzzy Control**

Fuzzy rule-based system, Fuzzification and Defuzzification, Fuzzy Control, Assumption in a Fuzzy control system Design, Design of Fuzzy Controllers, Fuzzy Control systems Models, Examples of Fuzzy systems

**Unit 10: Uncertainty Based Informations**

Uncertainty based Information, Simple, Joint and Conditional uncertainties, On-interactive sets, Information transmission, On-specificity of Fuzzy sets, Degree of validity of Credibility, Fuzziness, Total uncertainty, Fuzziness in evidence theory

**Unit 11: Decision making in Fuzzy Environment**

Individual Decision making, Multiperson Decision making, Multicriteria

Decision making, Fuzzy Rankin method

**Unit 12: Fuzzy Linear Programmemeing**

Fuzzy linear programmemeing, Special cases of Fuzzy linear programmemeing

**Unit 13: Fuzzy Topological Space**

Concept of a Fuzzy points and its Neighbourhood Structure, Fuzzy points and Level sets, Local base

**Unit 14: Fuzzy Product Induced Space**

Fuzzy product spaces, Fuzzy Continuity, Product-Induced Spaces

**Unit 15: Fuzzy Metric Space**

Fuzzy Metric Spaces, Fuzzy Metrization, Fuzzy Continuous Functions

**Suggested Readings:**

1. Mohan, C. An Introduction to Fuzzy Set Theory and Fuzzy Logic. Anshan Publishers, 2015.
2. Lee, K. H. First Course on Fuzzy Theory and Applications. Springer International Edition, 2005.
3. Yen, J., Langari, R. Fuzzy Logic - Intelligence, Control and Information Pearson Education, 1999.
4. Zimmerman, H.J. Fuzzy Set Theory and its Applications. Allied Publishers Ltd., New Delhi, 1991.