**MAHATMA GANDHI UNIVERSITY,**

 **KOTTAYAM, KERALA**

**SCHOOL OF MATHEMATICS & STATISTICS**

**M. Sc. MATHEMATICS**

**FACULTY OF SCIENCE**

**CURRICULUM AND SYLLABI**

**UNDER MAHATMA GANDHI UNIVERSITY CSS REGULATIONS 2020**

**(Revised According to OBE Scheme and 2021 Modifications)**

**EFFECTIVE FROM 2021-22 ACADEMIC YEAR ONWARDS**



**DEPARTMENT OF MATHEMATICS**

**MAHATMA GANDHI UNIVERSITY, KOTTAYAM**

**2021**

**Preface**

**Mahatma Gandhi University**

Mahatma Gandhi University is an Indian University based in Kottayam, Kerala State, established by the Govt. of Kerala in 1983, approved by UGC, and accredited with NAAC “A” Grade, 3.24 CGPA. With its academic excellence, the University has bagged Chancellor’s Award twice for the best University (2015-16 and 2017-18) within the state of Kerala. It has also secured 30thposition in NIRF ranking (April 2019) and 11th position in India Today-MDRA ranking,2018. CSIR has ranked the University 13th for its intellectual productivity and NISTADS has rated it as 19thin terms of h-index.

At present, Mahatma Gandhi University offers research programs in forty disciplines through its own Schools and approved Research Centers. It has close collaboration for academic, research and extension programs with a number of national agencies and institutions including the UGC, DST-FIST, DRS, ISRO, COSIT, DIT, DST (Nano Mission),CSIR, DAAD, STEC, ICMR, BARC and MOEF. The University is also involved in active collaboration with research institutions of international reputation such as the Max Planck Institute of Technology, Germany; Brown University, USA; University of Nantes, France; California Institute of Technology, USA; University of Toronto, Canada; Catholic University, Belgium; Heidelberg University, Germany; the Institute of Political Studies, Rennes, France; Trent University, Canada; IPF Dresden, Germany; University of Paris and University of Strasbourg.

Mahatma Gandhi University has made immense strides in the fields of inter disciplinary teaching and research. The faculty comprises of outstanding scholars, many of whom have made original contributions in their respective fields of specialization. The faculty members and research scholars of several departments have gained wide spread recognition for the commendable quality of their research publications. The web enabled University library has large collection of books, journals, e-journals and online theses. The digital library provides open access to its enviable collection of digitized Ph.D. dissertations. All these work in tandem with the academic business transacted by the University, making the whole experience a holistic one..

**Vision and Mission of MGU**

**Vision of Mahatma Gandhi University**

 **“Mahatma Gandhi University envisions to excel in the field of higher education and cater to the scholastic and developmental needs of the individual, through continuous creation of critical knowledge base for the society’s sustained and inclusive growth.”​**

**Mission of Mahatma Gandhi University**

* **To conduct and support undergraduate, postgraduate and research-level programmes of quality in different disciplines​**
* **To foster teaching, research and extension activities for the creation of new knowledge for the development of society​**
* **To help in the creation and development of manpower that would provide intellectual leadership to the community​**
* **To provide skilled manpower to the professional, industrial and service sectors in the country so as to meet global demands​**
* **To help promote the cultural heritage of the nation and preserve the environmental sustainability and quality of life ​**
* **To cater to the holistic development of the region through academic leadership​**

**OUTCOME BASED EDUCATION (OBE)**

The OBE is a 6 step process as shown in the following figure



**Figure: OBE Process**

The process is presented as a cycle or a loop. The cycle represents the continuous nature of assessing learning outcomes.

As envisaged by the IQAC of Mahatma Gandhi university, an OBE based curricularframework has been proposed for the School of Mathematics and Statistics from the academic year 2020-2021whichis presented hereafter.

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| --- | --- |
| Mahatma Gandhi University Recruitment 2021-2022 mgu.ac.in MGU Jobs | **Mahatma Gandhi University, Kottayam****Graduate attributes** |

|  |  |  |
| --- | --- | --- |
| Critical Thinking and Advice – The Entrepreneur's Tool | **Critical thinking and analytical reasoning** | Capability to analyze, evaluate and interpret evidence, arguments, claims, beliefs on the basis of empirical evidence; reflect relevant implications to the reality; formulate logical arguments; critically evaluate practices, policies and theories to develop knowledge and understanding; able to envisage the reflective thought to the implication on the society. |
| Productive problem-solving - Garden Center Magazine | **Scientific reasoning and Problem solving** | Ability to analyze, discuss, interpret and draw conclusions from quantitative/qualitative data and experimental evidences; and critically evaluate ideas, evidence and experiences from an unprejudiced and reasoned perspective; capacity to extrapolate from what one has learned and apply their competencies to solve problems and contextualize into research and apply one’s learning to real life situations. |
| Avishkaar Maker Board Training | **Multidisciplinary/ Interdisciplinary/ Transdisciplinary approach** | Acquire interdisciplinary /multidisciplinary/ transdisciplinary knowledge base as a consequence of the learning they engage with their programme of study; develop a collaborative-multidisciplinary/interdisciplinary/transdisciplinary- approach for formulate constructive arguments and rational analysis for achieving common goals and objectives. |
| Drama in Education: Developing Personal and Interpersonal Skills | Paideia | **Intra and Interpersonal skills** | Ability to work effectively and respectfully with diverse teams; facilitate collaborative and coordinated effort on the part of a group, and act together as a group or a team in the interests of a common cause and work efficiently as a member of a team; lead the team to guide people to the right destination, in a smooth and efficient way. |
| 31 Best Digital Literacy Organizations: Bridging the Digital Gap | **Digital literacy** | Capability to use ICT in a variety of learning situations, demonstrate ability to access, choose, collect and evaluate, and use a variety of relevant information sources; structure and evaluate those data for decision making. |
| Playful, Elegant, Learning Logo Design for Enriching Lives - inspiring Global  Citizenship by Iban641 | Design #6559682 | **Global Citizenship** | Building a sense of belonging to a common humanity and to become responsible and active global citizens. Appreciation and adaptation of different sociocultural setting and embrace and promote equity.  |
| Competence Social Stock Illustrations – 659 Competence Social Stock  Illustrations, Vectors & Clipart - Dreamstime | **Social competency** | Possess knowledge of the values and beliefs of multiple cultures, appreciate and adapt to a global perspective; and capability to effectively engage in a multicultural society and interact respectfully, manage and lead with diverse groups. |
| Council for Inclusive Capitalism with the Vatican | **Equity, Inclusiveness and Sustainability** | Appreciate and embrace equity, inclusiveness and sustainability and diversity; acquire ethical and moral reasoning and values of unity, secularism and national integration to enable to act as dignified citizens; able to understand and appreciate diversity |
| Create a trusting symbol that illustrates lifelong learning | Logo design  contest | 99designs | **Lifelong learning** | Continuous acquisition of knowledge and skills. Learn, unlearn and re-learn based on changing ecosystem. “Learning how to learn”, that are necessary for participating in learning activities throughout life, through self-paced and self-directed learning aimed at personal development, meeting economic, social and cultural objectives, and adapting to changing trades and demands of work place through knowledge/ skill development/ reskilling. |

|  |  |
| --- | --- |
| Mahatma Gandhi University Recruitment 2021-2022 mgu.ac.in MGU Jobs | **Mahatma Gandhi University, Kottayam****Programme Outcomes(PO)** |

1. **Critical Thinking and Analytical Reasoning**

Capability to analyse, evaluate and interpret evidence, arguments, claims, beliefs on the basis of empirical evidence; reflect relevant implications to the reality; formulate logical arguments; critically evaluate practices, policies and theories to develop knowledge and understanding; able to envisage the reflective thought to the implication on the society.

1. **Scientific Reasoning and Problem Solving**

Ability to analyse, discuss, interpret and draw conclusions from quantitative/qualitative data and experimental evidences; and critically evaluate ideas, evidence and experiences from an unprejudiced and reasoned perspective; capacity to extrapolate from what one has learned and apply their competencies to solve problems and contextualise into research and apply one’s learning to real life situations.

1. **Multidisciplinary/Interdisciplinary/Transdisciplinary Approach**

Acquire interdisciplinary /multidisciplinary/transdisciplinary knowledge base as a consequence of the learning they engage with their programme of study; develop a collaborative-multidisciplinary/interdisciplinary/transdisciplinary-approach for formulate constructive arguments and rational analysis for achieving common goals and objectives.

1. **Communication Skills**

Ability to reflect and express thoughts and ideas effectively in verbal and nonverbal way; Communicate with others using appropriate channel; confidently share one’s views and express herself/himself; demonstrate the ability to listen carefully, read and write analytically, and present complex information in a clear and concise manner and articulate in a specific context of communication.

1. **Leadership Skills**

Ability to work effectively and lead respectfully with diverse teams; setting direction, formulating goal, building a team who can help achieve the goal, motivating and inspiring team members to engage with that goal, and using management skills to guide people to the right destination, in a smooth and efficient way.

1. **Social Consciousness and Responsibility**

Ability to contemplate of the impact of research findings on conventional practices, and a clear understanding of responsibility towards societal needs and reaching the targets for attaining inclusive and sustainable development.

1. **Equity, Inclusiveness and Sustainability**

Appreciate equity, inclusiveness and sustainability and diversity; acquire ethical and moral reasoning and values of unity, secularism and national integration to enable to act as dignified citizens; able to understand and appreciate diversity, managing diversity and use of an inclusive approach to the extent possible.

1. **Moral and Ethical Reasoning**

Ability to embrace moral/ethical values in conducting one’s life, formulate a position/argument about an ethical issue from multiple perspectives, and use ethical practices in all work. Capable of demonstrating the ability to identify ethical issues related to one’s work and living as a dignified person in the society.

1. **Networking and Collaboration**

Acquire skills to be able to collaborate and network with scholars in an educational institutions, professional organizations, research organizations and individuals in India and abroad.

1. **Lifelong Learning**

Ability to acquire knowledge and skills, including “learning how to learn”, that are necessary for participating in learning activities throughout life, through self-paced and self-directed learning aimed at personal development, meeting economic, social and cultural objectives, and adapting to changing trades and demands of work place through knowledge/skill development/reskilling.

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| --- | --- |
| Mahatma Gandhi University Recruitment 2021-2022 mgu.ac.in MGU Jobs | **Mahatma Gandhi University, Kottayam****M. Sc. Mathematics - Programme Specific Objectives& Outcomes**  |

**Objectives:**

1. To provide advanced level teaching and training in theory and applications of mathematics and enable a career in teaching and research.
2. To provide a platform for talented students to undergo higher studies in the subject as well as to train them to suit for the needs of the society and industry.
3. To allow more flexibility to branch out into other emerging areas of Mathematics, Computer Science, Cryptography, Bio Informatics, Data Science etc.
4. To provide special attention to interdisciplinary areas in describing, exploring, analyzing and comparing data with an innovative research mind in a data driven world.
5. To impart training to pass national level tests like UGC-CSIR NET-JRF, GATE, NBHM examinations with a view to enable the students to get opportunities for teaching, research and employment in India and abroad.

**Outcomes:**

1. After undergoing this program, students will get advanced knowledge in theory and applications in all areas of Mathematics and Applied Mathematics including Industrial Mathematics, Financial Mathematics, Network Science, Epidemiology, Data Science, Cryptography, Coding Theory, Mathematical Biology etc.
2. Students are well trained to succeed in national level tests like UGC-CSIR NET-JRF, GATE, NBHM examinations, etc.
3. Students are motivated to pursue teaching and research in all emerging areas of research in theoretical and applied branches of Mathematics and related disciplines.
4. Students are well trained to meet the needs of industry as well as society in general.

**PROGRAMME STRUCTURE AND SYLLABI, SMS-MGU**

**M.Sc. MATHEMATICS**

**CURRICULUM COMMITTEE IN MATHEMATICS (PG)**

**Members :**

1. Prof. Ambat Vijayakumar, Emeritus Professor, Department of Mathematics, CUSAT, Kochi. (Chairman, Curriculum Committee)
2. Prof. A. K. Nandakumaran, Department of Mathematics, IISc., Banagalore.
3. Prof. B.V.Rajarama Bhat, Indian Statistical Institute, Bangalore.
4. Prof. Amrithanshu Prasad, The Institute of Mathematical Sciences, Chennai .
5. Prof. D. D. Somashekara, Department of Mathematics, University of Mysore.
6. Prof. K.S. Subrahamanian Moosath, IIST, Thiruvananthapuram
7. Prof. T. Jayaraj, SVR NSS College, Vazhoor (Chairman, PG Board of Studies in Mathematics, MG University, Kottayam)
8. Dr. K. K. Jose, Hon. Director, School of Mathematics & Statistics, M. G. University, Kottayam Email: kkj.smsda.mgu@gmail.com Mob: +91 9446560608 ( Convenor)

**SCHOOL OF MATHEMATICS & STATISTICS**

**M. Sc. MATHEMATICS DEGREE PROGRAMME**

**(Revised Under CSS Regulations 2020 & OBE Amendment w. e. f. 2021-22)**

1. **Objectives of the Program** :

In this era of information explosion, Mathematics has assumed a key role and distinct dimension, finding its applicability in diverse areas. This ranges from classical subjects like Physics and Chemistry to Systems Biology, Bio informatics, Mathematical Chemistry, Epidemiology etc. Though late, the decision to establish a School of Mathematics & Statistics in the Mahatma Gandhi University, Kottayam during 2020-21 is commendable especially since our state of Kerala had a strong tradition in Mathematical Sciences with the School of Mathematics during the period 1350-1650, popularly known as the Golden Age of Indian Mathematics.

 In the proposed curriculum for M.Sc. Mathematics , apart from teaching core subjects, like Algebra ,Analysis etc. the students will be encouraged to learn some interdisciplinary subjects like Discrete Mathematics, Wavelet Analysis, Cryptography, Coding Theory etc. The program prepares the students for UGC-CSIR- JRF/NET/GATE, NBHM examinations for providing teaching and research opportunities in established institutions of National importance like TIFR, ISI, CMI, IMSc.etc and universities abroad. The students will be exposed to the most relevant applications of Mathematics in topics like Network Science, Defense Science, Epidemiology etc. .

There will be an open course during third semester to encourage interdisciplinary studies and research. This can be selected from among courses offered by any other school/department/centre in the university. The Department will arrange expert lectures in the online mode by eminent researchers from all over the world. We expect students to select the elective courses to ensure employment and research opportunities in emerging areas.

1. **Eligibility for admissions:**

B.Sc. Degree in Mathematics/ Applied Mathematics with at least 50% marks ( CGPA 5.0 out of 10.00 under grading system) for the optional subjects taken together. Admission will be made through a common admission procedure (CAP) on the basis of a Common Admission Test (CAT) or a special test conducted for specific programmes by the Departments, as the case may be. Admission may be based on the written test alone or written test and interview or on the basis of the marks obtained in the qualifying examinations as well as the marks obtained in the written test, the interview as decided by the Faculty Council of Schools / Centres / Institutes from time totime in accordance with CSS regulations 2020.

1. **Examination :** Credit and Semester System (CSS)
2. **Medium of instruction and assessment** : English
3. **Duration of the Course : 4 Semesters (2 years)**

This is a regular course in which no private / distance mode will not be conducted. However, under extreme situations like COVID 19 pandemic, classes may be conducted online as per UGC guidelines and university rules. The duration of PG program shall be 4 semesters. The duration of each semester shall be 90 working days (18-20 weeks) including internal and external examinations. Odd semesters are normally from July to December and even semesters from January to June. A student shall be permitted to register for the program at the time of admission. A student who registers for the course shall complete the course within a period of 4 years from the date of commencement of the program.

1. **Courses and Credits:**

Every Program conducted under Credit Semester System shall be monitored by the Departmental Faculty Council. In all the programmes, three kinds of courses are offered; Core Courses (3-4 credits), Elective Courses (2-4 credits) and Open elective courses (4 credits). Core courses are offered by the Schools/Department/Centre/Institute conducting the programme.

Elective Courses shall be selected either from the same School/Department or from some other School/ Centres /Institutes. Any course chosen by a student, generally from an unrelated discipline / subject, from Schools/ Centres / Institutes other than own School/Department/Center, with an intention to seek broad exposure, is called an Open course. Students are required to take one open course in the Third semester. The details are given in Table of Courses and Credits.

A Semester shall, be worth a minimum of 16 credits. The minimum total credits for a postgraduate program shall be 80. A minimum of 4 credits and maximum of 20 credits shall be set apart for the project work/dissertation. The compulsory project/dissertation to be completed in the 4th semester of a postgraduate programme shall be prepared by the student under the guidance of a member of the faculty or, in the case of subjects, which so demand, an external guide, to be decided by the school’s faculty council.

University Departments / Schools are permitted to offer online UGC approved MOOC courses from SWAYAM platform ,Online courses offered by NPTEL,COURSERA as electives during 3rd and 4th semesters subject to the condition that the aggregate credits for such online courses shall not exceed 20% of total credits. These shall be coordinated by a faculty coordinator subject to the approval of the faculty council.

1. **Outcome Based Education (OBE)**

M.G.University has implemented OBE Scheme in 2021. Outcome Based Education (OBE) is an educational approach and a learning philosophy, which envisages organizing the entire academic programs (curriculum) and instructional efforts around clearly defined ‘outcomes’ that an institution want all students to accomplish when they complete the programme. The purpose of outcome based approach is to ensure that students achieve learning expectations for the programs in which they participate. The fundamental premise underlying the learning outcomes-based approach to curriculum planning and development is that higher education qualifications are awarded on the basis of demonstrated achievement of outcomes (expressed in terms of knowledge, understanding, skills, attitudes and values) and academic standards expected. The expected learning outcomes are used as reference points that would help formulate graduate attributes, qualification descriptors, programme outcomes and course outcomes which in turn will help in curriculum planning and development, and in the design, delivery and review of academic programmes. They provide general guidance for articulating the essential learnings associated with programmes of study and courses with in a programme.

**Key outcomes of Curriculum planning and development:** The key outcomes that underpin the curriculum planning and development reflect the Graduate Attributes visible in the high level qualities, skills and knowledge that a student expected to gain as a result of the learning and experiences they imbibe from a programme of study. Outcomes for a post graduate programme is defined at three levels as: (1) Programme Outcomes (POs), (2) Programme Specific Outcomes (PSOs), and (3) Course Outcomes (COs).

**Graduate Attributes:** The graduate attributes reflect the particular quality and feature or characteristics of an individual, including the knowledge, skills, attitudes and values that are expected to be acquired by a student through studies at a higher education institution. The graduate attributes include capabilities that help strengthen one’s abilities for widening current knowledge base and skills, gaining new knowledge and skills, undertaking future studies, performing well in a chosen career and playing a constructive role as a responsible citizen in the society. The graduate attributes define the characteristics of a student&#39;s university degree programme and describe a set of characteristics/competencies that are transferable beyond study of a particular subject area and programme contexts in which they have been developed.

**Programme Outcomes (PO):** A programme Outcome (PO) indicates the generic outcomes and attributes expected for the award of a particular type of qualification. The qualification descriptors reflect both disciplinary knowledge and understanding as well as generic skills, including global competencies that all students in different academic fields of study should acquire/attain and demonstrate.

**Programme Specific outcome (PSO):** Programme specific outcome (PSO) will include subject-specific skills and generic skills, including transferable global skills and competencies, the achievement of which the students of a specific programme of study should be able to demonstrate for the award of a Degree qualification. The programme outcomes are attained by learners through the essential learning acquired on completion of selected courses of study within a programme.

**Course outcome (CO):** Course outcomes are specific to the learning for a given course of study related to a disciplinary or interdisciplinary/multi-disciplinary area. Some programmes of study are highly structured, with a closely laid down progression of compulsory/core courses to be taken at particular phases/stages of learning. Course-level outcomes will be aligned to programme specific outcomes Course outcomes are specific to a course of study within a given programme of study.

1. **Teaching Learning and Assessment**

The teaching, learning and assessment strategies are coined with the outcomes set in the OBE teaching and learning framework. The teaching, learning, and assessment mechanism is designed within the principles of the behaviour elements of educational activities such as cognitive, psychomotor, affective, and social domains.

1. **Question paper setting** : The Overall weightage in the assessment, to each of Bloom’s learning levels

Any question paper which assess the learning outcome should be set with the following learning levels in mind so as to assess the learning outcome attained by a specific learner.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Sl.No. | Learning level | Question cues | Range Marks (%) for each section | Range of Total Marks/60 |
| 1 | Creating | design, formulate, build, invent, create, compose, generate, derive, modify, develop, integrate | 10-20 | 6-12 |
| 2 | Evaluating | assess, decide, choose, rank, grade, test, measure, defend, recommend, convince, select, judge, support, conclude, argue, justify, compare, summarize, evaluate | 20-30 | 12-18 |
| 3 | Analyzing | classify, outline, break down, categorize, analyze, diagram, illustrate, infer, select | 20-30 | 12-18 |
| 4 | Applying | apply, solve, illustrate, use, demonstrate, determine, model, experiment, show, examine, modify, calculate, predict | 40-50 | 24-30 |
| 5 | Understanding  | describe, explain, paraphrase, restate, associate, contrast, summarize, differentiate interpret, discuss | 20-30 | 12-18 |
| 6 | Remembering  | state, define, describe, recall, identify, show, label, tabulate, quote, name, who, when, where | 10-20 | 6-8 |
| Total |  |  100 | 60 |

1. **Pattern of Question Paper for End-Semester Examination**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Sl. No** | **Type of Question** | **No of questions to be answered** | **Marks for each question** | **Total Marks** |
| 1 | Essay Type  | 2 out of 4 | 10 | 20 |
| 2 | Short Answer Type | 5 out of 8 | 5 | 25 |
| 3 | Very Short Answer Type | 5 out of 8 | 2 | 10 |
| 4 | MCQ (Objective Type) | 5 out of 5 | 1 | 05 |
| Total | 17 out of 25 |  -- | 60 |

Questions shall be set to assess knowledge acquired, standard application of knowledge, application of knowledge in new situations, critical evaluation of knowledge, the ability to synthesize knowledge and create new ideas out of knowledge. The question setter shall ensure that questions covering all skills are included. A question paper shall be a judicious mix of essay type, short answer, very short answer type and Multiple-Choice questions. The type of questions and the marks assigned to them are as follows.

1. **Evaluation and Grading**

The CSS rules and regulations for University Departments and Schools will be applicable. Evaluation scheme for each course shall contain 2 parts (a) Internal Continuous Assessment (CA) and (b) External End Semester Assessment (SA). A weightage of 40% is given to continuous internal assessment and 60 % to end semester external evaluation. Both internal and external evaluation is carried out in accordance with the grading system as given in the CSS regulations. Normally odd semester ESA is through examiners in the department. But for even semesters, external examiners will also be included in the board of examiners and there will be double valuation.

1. **Faculty under which the Degree is awarded** : Science
2. **Specializations offered if any** : List of Electives enclosed
3. **Note on compliance with UGC Minimum Standards for the conduct and award of Post Graduate Degrees**:

 Present syllabus is in compliance with UGC Minimum Standards to award Post Graduate Degree. It is ideal if one enjoys Mathematics and Statistics and would like to use his skills to model future events and risk.

1. **The Program Structure:**

**Table of Courses and Credits**

|  |  |  |  |
| --- | --- | --- | --- |
| Course Code | Course Title | Teaching L+T+P | Credits |
| **SEMESTER I Total Credits 24** |
| MS M 21 C01 | LINEAR ALGEBRA | 4 +1+0 | 4 |
| MS M 21 C02 | ALGEBRA- I | 4 +1+0 | 4 |
| MS M 21 C03 | TOPOLOGY | 4 +1+0 | 4 |
| MS M 21 C04 | REAL ANALYSIS – I | 4 +1+0 | 4 |
| MS M 21 C05 | DISCRETE MATHEMATICS | 4+ 1+0 | 4 |
| MS M 21 C06 | ORDINARY DIFFERENTIAL EQUATIONS | 4 +1+0 | 4 |
| **SEMESTER II Total Credits 24** |
| MS M 21 C07 | ALGEBRA –II | 4 +1+0 | 4 |
| MS M 21 C08 | REAL ANALYSIS- II | 4 +1+0 | 4 |
| MS M 21 C09 | COMPLEX ANALYSIS | 4 +1+0 | 4 |
| MS M 21 C10 | FUNCTIONAL ANALYSIS | 4 +1+0 | 4 |
|  | ELECTIVE 1 | 4 +1+0 | 4 |
|  | ELECTIVE 2 | 4 +1+0 | 4 |
| **SEMESTER III Total Credits 24** |
| MS M 21 C11 | MULTIVARIABLE CALCULUS & GEOMETRY | 4 +1+0 | 4 |
| MS M 21 C12 | ANALYTIC NUMBER THEORY | 4 +1+0 | 4 |
| MS M 21 C13 | PROBABILITY THEORY | 4 +1+0 | 4 |
|  | ELECTIVE 3 | 4 +1+0 | 4 |
|  | ELECTIVE 4 | 4 +1+0 | 4 |
|  | OPEN COURSE |  | 4 |
| **SEMESTER IV Total Credits 16** |
|  | ELECTIVE 5 | 4+1+0 | 4 |
| MS M 21 C14 | PROJECT WORK / DISSERTATION | 20 | 12 |
|  | **Grand Total of Credits** |  | **88** |

Thus in the present Program Structure there are 14 Core Courses with a total of 64 credits, 5 Elective courses with a total of 20 credits and an Open Course of 4 credits so that the grand total of credits is 88 for the whole program.

**N.B.1** Open Course is any course offered by another Department / School / Inter university Centre of the University other than the parent Department / School/ Centre, permitted by both Departments / Schools to encourage interdisciplinary studies and research in emerging areas.

**N.B.2** In case students wish to undergo online MOOC Courses in SWAYAM PORTAL or offered by IITs, NPTEL, COURSERA and other reputed institutes of national importance, they can choose them as electives during Semester 3 and 4 with the permission of the Head of the Department / Director of the School in accordance with the CSS regulations of the university.

**N.B.3** Project / Dissertation shall be carried out in a reputed research institute/ department or industry under the joint supervision of an internal faculty and external guide / expert approved by the Director / Head of the Dept. Literature Survey, Review of Literature etc. on Project Work/ Dissertation should start in the Third Semester & a Brief Report to be Submitted to the Supervising Faculty/ Head of the Dept. The students have to submit a bound copy and soft copy of the Project Report (documented in LaTex) of at least 50 pages certified by the supervisors, at least 7 days before the conduct of the Presentation and Viva Voce. The Project/ Dissertation will be valued with respect to various criteria including content and presentation as decided by the University as per CSS Rules & Regulations. The marks for Content of Project Report/ Dissertation and Viva Voce shall be in the ratio 80: 20.

1. **Table of Elective Courses and Open Courses:**

Students can select any 5 elective courses from the list of electives given below. More electives may be added and offered with the permission of the competent authorities.

|  |  |  |  |
| --- | --- | --- | --- |
| **Course Code** | **NAME OF THE COURSE** | **Teaching**  | **Credits** |
| MS M21 E01 | PARTIAL DIFFERENTIAL EQUATIONS | 4 | 4 |
| MS M21 E02 | DIFFERENTIAL GEOMETRY | 4 | 4 |
| MS M21 E03 | ALGEBRAIC TOPOLOGY | 4 | 4 |
| MS M21 E04 | ADVANCED FUNCTIONAL ANALYSIS  | 4 | 4 |
| MS M21 E05 | ADVANCED COMPLEX ANALYSIS | 4 | 4 |
| MS M21 E06 | CODING THEORY | 4 | 4 |
| MS M21 E07 | ALGEBRAIC NUMBER THEORY | 4 | 4 |
| MS M21 E08 | WAVELETS | 4 | 4 |
| MS M21 E09 | GRAPHS & MATRICES | 4 | 4 |
| MS M21 E10 | REPRESENTATION THEORY | 4 | 4 |
| MS M21 E11 | LINEAR PROGRAMMING | 4 | 4 |
| MS M21 E12 | CRYPTOGRAPHY | 4 | 4 |
| MS M21 E13 | OPERATIONS RESEARCH | 4 | 4 |
| MS M21 E14 | DATA SCIENCE & DATA ANALYTICS | 4 | 4 |
| MS M21 E15 | STOCHASTIC PROCESSES | 4 | 4 |
| MS M21 E16 | MATHEMATICS FOR GENETICS AND ECOLOGY | 4 | 4 |
| MS M21 E17 | ACTURIAL MATHEMATICS | 4 | 4 |
| MS M21 E18 | NUMERICAL ANALYSIS WITH PYTHON 3 | 4 | 4 |
| **Open Course During Semester III for students of Schools/Departments/ Centres other than the School of Mathematics and Statistics** |
| MS M 21 O 01 | ADVANCED RESEARCH METHODOLOGY | 4 | 4 |

1. **Process of Evaluation:**

The internal assessment will be a continuous assessment (CA) that accounts for 40% of the evaluation in both theory and practical. The end semester examination will account for the remaining 60% of the evaluation.

End-Semester Examination: The end semester examination will account for 60% of the evaluation. The evaluation of the end-semester examination of the first and third semesters shall be done by the faculty who taught the course. Evaluation of the 2nd and 4th semester courses based on questions set by external question paper setters shall be evaluated by two examiners; one, the external (as far as possible the question paper setter shall evaluate the examination paper as well) and the other, internal examiner.

The double valuation of answer scripts in the second and the fourth semester courses shall be done by external examiners and the concerned faculty respectively as approved by the Faculty Council.

The Head of the School/Department/Centres/Institutes will make arrangements for the evaluation of the answer scripts. The project/dissertation shall be evaluated by two examiners, one of them the faculty member who supervised the project and the other an external examiner to be decided by the HOD from a panel recommended by faculty council and approved by the Vice Chancellor. The comprehensive viva-voce, if any, must be carried out along with project evaluation.

Continuous Assessment (CA): The student’s participation and classroom performance as well as the feedback received from tests, tutorials, assignments and term papers shall form the basis for continuous assessment (CA). It accounts for 40% of the evaluation in both theory and practical. This assessment shall be based on a predetermined transparent system involving periodic written tests, assignments and seminars in respect of theory courses and based on tests, lab skill, records/viva and attendance in respect of practical courses.

 The percentage of marks assigned to various components for internal evaluation is as follows:

**a. Theory**

|  |  |  |
| --- | --- | --- |
| **Sl. No.** | **Component** | **% of internal marks** |
| i. | Test papers | 50% |
| ii. | Assignments/Book review/debates | 25% |
| iii. | Seminars/Presentation of case study | 25% |

For each course there shall be at least two class tests during a semester. Average of the best of the marks obtained in the two tests (in the case of more than two tests) or the average of the tests ( if there is only two tests) will be counted as the internal test component of CA.

 **b. Practical**

The evaluation for practical work shall be fully based on Continuous Internal Assessment as per criteria given in the table below.

|  |  |  |
| --- | --- | --- |
| **Sl. No.** | **Component** | **% of internal marks** |
| i. | Lab / Experiment skill | 40 % |
| ii. | Lab Records / Reports | 20 % |
| iii. | Lab Discipline (punctuality, participation, accuracy) | 20% |
| iv. | Viva Voce | 20% |

**Test Paper:** Valued answer scripts shall be made available to the students for perusal within 10 working days from the date of the tests.

**Assignments:** Each student shall be required to do 2 assignments/book reviews for each course. Assignments/book review after valuation must be returned to the students. The teacher shall define the expected quality of the above in terms of structure, content, presentation and the like, and inform the same to the students. Punctuality in submission of assignments/records is to be given a weightage in the internal evaluation.

**Seminar:** Every student shall deliver one seminar as an internal component of every course and must be evaluated by the respective course teacher in terms of structure, content, presentation and interaction. The soft and hard copies of the seminar report are to be submitted to the teacher in charge.

**Results of Continuous Assessment:** The results of the CA counter-signed by Head of the school shall be displayed on the notice board 5 days before the end semester examinations. The marks awarded for various components of the CA shall not be rounded off, if it has a decimal part. The total marks of the CA shall be rounded off to the nearest whole number. Relevant records of continuous assessment (CA) must be kept in the department and that must be made available for verification.

**Project Work:** There shall be a project/dissertation to be undertaken by all students. The dissertation entails field work, lab work, report writing, presentation and viva voce. The class hours allotted for project work may be clustered into a single slot so that students can do their work at a centre /location for a continuous period of time. However, appropriate changes can be made by the faculty council in this regard. Project/dissertation shall be carried out under the supervision of a teacher in the parent School/Centre/Institute or other research institutes or industrial establishment or university departments if they permit the students to do so, after getting permission from the Department Head.

 In such cases, one of the teachers from the schools/centres/institutes would be the co- supervisor/internal guide and an expert from the industry/ research organization concerned shall act as supervisor/ external guide. In the case of M Phil programme while forwarding the mark lists of the second semester to the CSS, director of the school/centre/institute shall ensure that both the hard and soft copies of the project/dissertation of all students will be handed over to the University Library immediately after the publication of the results.

**External Evaluation of Theory Answer Scripts:** The external evaluation shall be done after the examination at the earliest, preferably in a centralized valuation. As far as possible bar coded Answer Books shall be used to ensure confidentiality. The evaluation of the answer scripts shall be done by examiners based on a well-defined scheme of valuation. End semester evaluation of Theory Answer Scripts shall be conducted and evaluated by one internal examiner for odd semesters. For even semesters, one external and one internal examiner shall do the process of evaluation. That is, there shall be double valuation system of answer books in the 2nd and 4th Semester evaluations. The final marks awarded will be the average of both valuations. If there is a variation of more than 10 % of the maximum marks, the answer books shall be valued by a third external examiner appointed by the director. The final marks to be awarded shall be the average of the nearest two best out of three awarded by all the examiners.

**Internal Evaluation**

Internal Evaluation will be conducted as Continuous Assessment according to CSS Guidelines 2020 and will consist of Test Papers, Assignments and Seminars/ presentations for theory. For Practical Courses timely submission of practical records, test papers, lab skills in practical works and viva voce / presentations.

**SEMESTER-WISE SYLLABI**

**FIRST SEMESTER COURSES - TOTAL CREDITS 24**

|  |  |  |  |
| --- | --- | --- | --- |
| **Course code** | **NAME OF THE COURSE** | **Teaching hrs** | **Credits** |
| MS M 21 C01 | LINEAR ALGEBRA | 4 +1+0 | 4 |
| MS M 21 C02 | ALGEBRA- I | 4 +1+0 | 4 |
| MS M 21 C03 | TOPOLOGY | 4 +1+0 | 4 |
| MS M 21 C04 | REAL ANALYSIS – I | 4 +1+0 | 4 |
| MS M 21 C05 | DISCRETE MATHEMATICS | 4 +1+0 | 4 |
| MS M 21 C06 | ORDINARY DIFFERENTIAL EQUATIONS | 4 +1+0 | 4 |
|  |  **Total Credits** |  | **24** |

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|  | **MAHATMA GANDHI UNIVERSITY, KOTTAYAM** |
| **MS M 21 C01: LINEAR ALGEBRA** |

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| School Name | School of Mathematics and Statistics |
| Programme | MSc Mathematics |
| Course Name  | Linear Algebra |
| Type of Course | Core |
| Course Code | MS M 21 C01 |
| Course Objectives | This course starts with the review of system of linear equations, vector spaces and linear transformations. It also covers polynomial rings, determinants, elementary canonical forms, and direct sum decompositions. |
| Semester  | First |
| Total Student Learning Time (SLT) | Learning Approach | Lecture | Tutorial | Practical | Others | Total LearningHours |
|  | Authentic learningCollaborative learning Independent learning | 80 | 20 | 0 | 20 | 120 |
| Pre-requisite |  Basics of Linear Algebra |

**COURSE OUTCOMES (CO)**

|  |  |  |  |
| --- | --- | --- | --- |
| **CO No.** | **Expected Course Outcome** | **Learning Domains**  | **PSO No.** |
| 1 | The student should be able to have a clear understanding of vector spaces, linear transformations, coordinates and the representation of transformation by matrices. | U/R  | 1,2 |
| 2 | Have knowledge about the concepts linear functional, double dual, algebra of polynomials and the prime factorization of polynomials. | U/ An | 1,2 |
| 3 | Also gets an ability for solving problems in these areas. | U/S | 1,2 |
| 4 | Understand the concepts determinants, properties of determinants, characteristic values, characteristic vectors and get an ability for solving problems in these areas. | U/A | 1,2 |
| **\**Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** |

**COURSE CONTENT**

|  |  |  |  |
| --- | --- | --- | --- |
| **Module No** | **Module Content** | **CO** | **Hrs** |
| 1 | Vector spaces, subspaces, basis and dimension Co-ordinates, summary of row-equivalence, Computations concerning subspaces.(Chapter 2- 2.1, 2.2, 2.3, 2.4, 2.5 & 2.6 of the text) | 1 | 20 |
| 2 | Linear transformations, the algebra of linear transformations, isomorphism, representation of transformations by matrices, linear functional, double dual, transpose of a linear transformation.(Chapter 3 - 3.1, 3.2, 3.3, 3.4, 3.5, 3.6 & 3.7 of the text) | 2 | 20 |
| 3. | Determinants: Commutative Rings, Determinant functions, Permutation and uniqueness of determinants, Additional properties of determinants.(Chapter 5 - 5.1, 5.2, 5.3 & 5.4 of the text) | 3 | 20 |
| 4 | Introduction to elementary canonical forms, characteristic values, annihilatory Polynomials, invariant subspaces, Direct sum Decompositions(Chapter 6 - 6.1, 6.2, 6.3, 6.4, 6.6 of the text) | 4 | 20 |
| **Total Credits of the Course** | 4 | 80 |

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| **Text Book:**  |
| Kenneth Hoffman / Ray Kunze, Linear Algebra, Prentice-Hall of India Pvt. Ltd. Second Edition, New Delhi, 1992. |
| **References** |
| 1. M. Artin, Algebra, Prentice-Hall, (1991).
2. Serge Lang, Introduction to Linear Algebra, Second Edition, Springer (1997).
3. K.T Leung, Linear Algebra and Geometry, Hong Kong University Press, (1974).
4. S. Kumaresan, Linear Algebra: A Geometric Approach, Fist Edition PHI Learning (2009).
5. Sheldon Axler, Linear Algebra Done Right, Second Edition, Springer, (1997).
6. Richard Kaye and Robert Wilson, Linear Algebra, Oxford University Press, (1998).
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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)**Direct Instruction, Explicit Teaching, E-learning, interactive Instruction:, Active co-operative learning, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student/ Group representative |
| **Assessment Types** | **Mode of Assessment** 1. **Continuous Internal Assessment (CIA)**
	* Internal Test -20 marks
	* Assignment – Every student needs to write an assignment on a given topic based on the available published literature – 10 marks
	* Seminar Presentation – A topic needs to be presented and discussed with the class- 10 marks
2. **Semester End examination – 60 marks**
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|  | **MAHATMA GANDHI UNIVERSITY, KOTTAYAM** |
| **MS M 21 C02: ALGEBRA-I** |

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| School Name | School of Mathematics and Statistics |
| Programme | MSc Mathematics |
| Course Name  | Algebra – I |
| Type of Course | Core |
| Course Code | MS M 21 C02 |
| Course Objectives | This course starts with the basic algebraic structures Groups and studies various aspects of groups. It also covers group action on a set, Sylow theorems, Fermat’s and Euler’s theorems, Prime and maximal ideals. |
| Semester  | First |
| Total Student Learning Time (SLT) | Learning Approach | Lecture | Tutorial | Practical | Others | Total LearningHours |
|  | Authentic learningCollaborative learning Independent learning | 80 | 20 | 0 | 20 | 120 |
| Pre-requisite |  Basics of Set Theory, Group Theory |

**COURSE OUTCOMES (CO)**

|  |  |  |  |
| --- | --- | --- | --- |
| **CO No.** | **Expected Course Outcome** | **Learning Domains**  | **PSO No.** |
| 1 | To have a working knowledge of the concepts such as definition of a group, order of a finite group and order of an element.  | U/R  | 1,2 |
| 2 | Will have knowledge on advanced topics such as Sylow’s theorem and should be able to apply this result. | U/ An | 1,2 |
| 3 | Knowledge on Field Theory and Factorization of polynomials | U/S | 1,2 |
| 4 | Knowledge on Factor rings and various ideals | U/A | 1,2 |
| **\**Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** |

**COURSE CONTENT**

|  |  |  |  |
| --- | --- | --- | --- |
| **Module No** | **Module Content** | **CO** | **Hrs** |
| 1 | Direct products and finitely generated Abelian groups, fundamental theorem, Applications Factor groups, Fundamental homomorphism theorem, normal subgroups and inner automorphisms. Group action on a set, Isotropy subgroups, Applications of G- sets to counting.(Part II – Sections 11, 14, 16 & 17)  | 1 | 20 |
| 2 | Isomorphism theorems, Sylow theorems, Applications of the Sylow theory. (Part VII Sections 34, 36 & 37) | 2 | 20 |
| 3. | Fermat’s and Euler Theorems, The field of quotients of an integral domain, Rings of polynomials, Factorisation of polynomials over a field. (Part IV – Sections 20, 21, 22 & 23 )  | 3 | 20 |
| 4 | Non commutative examples, Homeomorphisms and factor rings, Prime and Maximal Ideals(Part IV – Sections 24, 26 &27) | 4 | 20 |
| **Total Credits of the Course** | 4 | 80 |

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| **Text Book:**  |
| John B. Fraleigh, A First Course in Abstract Algebra, 7thedition, Pearson Education. |
| **References** |
| 1. Algebra - M. Artin, Second Edition, Pearson.
2. Contemporary Abstract Algebra - J. A. Gallian, 4th Edition, Narosa.
3. Topics in Algebra - I.N. Herstein, Second Edition, Wiley Student Edition.
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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)**Direct Instruction, Explicit Teaching, E-learning, interactive Instruction:, Active co-operative learning, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student/ Group representative |
| **Assessment Types** | **Mode of Assessment** 1. **Continuous Internal Assessment (CIA)**
	* Internal Test -20 marks
	* Assignment – Every student needs to write an assignment on a given topic based on the available published literature – 10 marks
	* Seminar Presentation – A topic needs to be presented and discussed with the class- 10 marks
2. **Semester End examination – 60 marks**
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|  | **MAHATMA GANDHI UNIVERSITY, KOTTAYAM** |
| **MS M 21 C03: TOPOLOGY I** |

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| School Name | School of Mathematics and Statistics |
| Programme | MSc Mathematics |
| Course Name  | Topology – I |
| Type of Course | Core |
| Course Code | MS M 21 C03 |
| Course Objectives | Topology is essentially the study of surfaces in which normally non geometric properties are studied. This course introduces the basic concepts of topology and standard properties such as compactness, connectedness, and separation axioms. Also product topology, metrizability, Extension theorem in metric spaces. |
| Semester  | First |
| Total Student Learning Time (SLT) | Learning Approach | Lecture | Tutorial | Practical | Others | Total LearningHours |
|  | Authentic learningCollaborative learning Independent learning | 75 | 20 | 0 | 25 | 120 |
| Pre-requisite |  Basics of Set Theory |

**COURSE OUTCOMES (CO)**

|  |  |  |  |
| --- | --- | --- | --- |
| **CO No.** | **Expected Course Outcome** | **Learning Domains**  | **PSO No.** |
| 1 | The students will have a sound knowledge of one of the most abstract notions in Mathematics, Topology. | U/R  | 1,2 |
| 2 | He/she gains the idea of creating a new topological space from an existing one.  | U/ An/A | 1,2 |
| 3 | Understands the concept of metrizability | U | 1,2 |
| 4 | Basic Knowledge on connectedness and compactness | U/A | 1,2 |
| **\**Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** |

**COURSE CONTENT**

|  |  |  |  |
| --- | --- | --- | --- |
| **Module No** | **Module Content** | **CO** | **Hrs** |
| 1 | Open sets, Basis for Topology, closed sets, examples of Topologies in applications, interior, closure, limit point, the boundary of a set(Chapters 1, 2) | 1 | 17 |
| 2 | Creating new Topological spaces, The subspace Topology, product Topology, continuous functions, homeomorphisms(Chapters 3, 4) | 2 | 20 |
| 3. | Metric Spaces, Properties of Metric spaces, Metrizability(Chapter 5) | 3 | 18 |
| 4 | Connectedness, intermediate value theorem, path connectedness, compactness, compactness in Metric spaces, Extreme value theorem, limit point compactness, Tietze’s Extension theorem for metric space(Chapters 6, 7) | 4 | 20 |
| **Total Credits of the Course** | 4 |  |

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| **Text Book:**  |
| Introduction to Topology- Pure & Applied: Colin Adams & Robert Franzosa; Pearson: 2009. |
| **References** |
| 1. Under graduate Topology; Robert H Kasriel; Saunders Publications;1971.
2. Metric spaces; Michealo Searcoid; Springer; 2017.
3. Topolgy; James Dugundji; W.C. Brown Publishers, 1989.
4. Topology a first course ; James K Munkres ; Prentice Hall;
5. General Topology: Stephen Willard; Dover Publications; 1998.
6. Introduction to Topology and Modern Analysis; G.F.Simmons; McGraw Hill;1963.
7. Basic Topology; M.A.Armstrong; Springer; 2000.
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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)**Direct Instruction, Explicit Teaching, E-learning, interactive Instruction:, Active co-operative learning, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student/ Group representative |
| **Assessment Types** | **Mode of Assessment** 1. **Continuous Internal Assessment (CIA)**
	* Internal Test -20 marks
	* Assignment – Every student needs to write an assignment on a given topic based on the available published literature – 10 marks
	* Seminar Presentation – A topic needs to be presented and discussed with the class- 10 marks
2. **Semester End examination – 60 marks**
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|  | **MAHATMA GANDHI UNIVERSITY, KOTTAYAM** |
| **MS M 21 C04: REAL ANALYSIS I** |

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| School Name | School of Mathematics and Statistics |
| Programme | MSc Mathematics |
| Course Name  | Real Analysis – I |
| Type of Course | Core |
| Course Code | MS M 21 C04 |
| Course Objectives | ThiscoursestartswiththestructureofRealNumbers. Thiscourseisplannedto introduce the notions Differentiation, Integration and the convergence of sequence of functions.  |
| Semester  | First |
| Total Student Learning Time (SLT) | Learning Approach | Lecture | Tutorial | Practical | Others | Total LearningHours |
|  | Authentic learningCollaborative learning Independent learning | 75 | 20 | 0 | 25 | 120 |
| Pre-requisite |  Basics of Mathematical Analysis |

**COURSE OUTCOMES (CO)**

|  |  |  |  |
| --- | --- | --- | --- |
| **CO No.** | **Expected Course Outcome** | **Learning Domains**  | **PSO No.** |
| 1 | To get familiar with the concept of Metric Spaces  | U/R  | 1,2 |
| 2 | To get familiar with the concept of multivariable Differentiation  | U/A | 1,2 |
| 3 | Basic knowledge on advanced Integration - Riemann – Steiltjes Integrals  | U/A | 1,2 |
| 4 | Create an insight to Uniform convergence and related topics | U/A | 1,2 |
| **\**Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** |

**COURSE CONTENT**

|  |  |  |  |
| --- | --- | --- | --- |
| **Module No** | **Module Content** | **CO** | **Hrs** |
| 1 | Metric Spaces; Definition and examples, open and closed sets in metric space, compactness, connectedness. Continuity, Uniform continuity, types of discontinuities. | 1 | 15 |
| 2 | Derivative: Derivatives and continuity, L Hospital Rules, Mean-Value, Derivatives of vector-valued functions. | 2 | 20 |
| 3. | The Riemann-Steiltjes integrals, Fundamental theorem of Calculus, Differentiation under integral signs, integration under vector valued function, rectifiable curves. | 3 | 20 |
| 4 | Sequences and series of functions: Uniform convergence, Uniform convergence and continuity, Uniform convergence and integration, Uniform convergence and differentiation. Equicontinuous families of functions, Stone-Weierstrass Theorem, Power series. | 4 | 20 |
| **Total Credits of the Course** | 4 |  |

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| **Text Book:**  |
| Walter Rudin, Principles of Mathematical analysis, 3rd edition, McGraw-Hill Higher Education (1976). |
| **References** |
| 1. D Somasundaram and B. Choudhary, A first course in mathematical analysis, Narosa 1996.
2. Halsey L. Royden, Real Analysis, Prentice Hall, Upper Saddle River, NJ, (1988).
3. Tom M. Apostol, Mathematical Analysis, Addison-Wesley, Reading, MA, (1974).
4. K. A. Ross, Elementary Analysis; Theory of Calculus, Springer-Verlag, (2013).
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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)**Direct Instruction, Explicit Teaching, E-learning, interactive Instruction:, Active co-operative learning, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student/ Group representative |
| **Assessment Types** | **Mode of Assessment** 1. **Continuous Internal Assessment (CIA)**
	* Internal Test -20 marks
	* Assignment – Every student needs to write an assignment on a given topic based on the available published literature – 10 marks
	* Seminar Presentation – A topic needs to be presented and discussed with the class- 10 marks
2. **Semester End examination – 60 marks**
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|  | **MAHATMA GANDHI UNIVERSITY, KOTTAYAM** |
| **MS M 21 C05: DISCRETE MATHEMATICS** |

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| --- | --- |
| School Name | School of Mathematics and Statistics |
| Programme | MSc Mathematics |
| Course Name  | Discrete Mathematics |
| Type of Course | Core |
| Course Code | MS M 21 C05 |
| Course Objectives | This course gives a thorough introduction to Discrete Mathematics with a gentle introduction to Graph theory, basic counting principles, and Boolean Algebra. |
| Semester  | First |
| Total Student Learning Time (SLT) | Learning Approach | Lecture | Tutorial | Practical | Others | Total LearningHours |
|  | Authentic learningCollaborative learning Independent learning | 75 | 20 | 0 | 25 | 120 |
| Pre-requisite |  ----- |

**COURSE OUTCOMES (CO)**

|  |  |  |  |
| --- | --- | --- | --- |
| **CO No.** | **Expected Course Outcome** | **Learning Domains**  | **PSO No.** |
| 1 | The student will achieve a foundation of Graph Theory | U/R/A  | 1,2 |
| 2 | Familiarize students with Applications of Graph Theory | U/A | 1,2 |
| 3 | Get Basic knowledge on combinatorics  | U/A | 1,2 |
| 4 | Basic knowledge on Boolean Algebras | U/A | 1,2 |
| **\**Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** |

**COURSE CONTENT**

|  |  |  |  |
| --- | --- | --- | --- |
| **Module No** | **Module Content** | **CO** | **Hrs** |
| 1 | Graph Theory. An introduction to graph. Definition of a Graph, More definitions, Vertex Degrees, Sub graphs, Paths and cycles, the matrix representation of graphs.Text 1: Chapter 1 (Sections 1.1 to 1.7)  | 1 | 20 |
| 2 | Trees. Definitions and Simple properties, Bridges, Spanning trees. Cut vertices and Connectivity. Euler’s Tours, the Chinese postman problem. Hamiltonian graphs & the travelling salesman problem. Text 1: Chapter 2 (Sections 2.1, 2.2 & 2.3, 2.6); Chapter 3 (Sections 3.1 to 3.4 ) | 2 | 20 |
| 3. | Counting, Basic counting principles, Permutations, Combinations, Pigeon-hole principle, Inclusion-exclusion principle, Ordered-unordered partitions. Recurrence Relations, Introduction, Two examples, Linear homogeneous recurrence relations, General Linear recurrence relations.Text 2: Chapter 6 (Sections 6.1-6.8) , Text 3( Sections 6.1-6.4) | 3 | 20 |
| 4 | Boolean algebra, Representation theorem, Minimal Boolean expressions, Logic gates, Boolean functions.Text 2: Chapter 15 (Sections 15.1-15.11)  | 4 | 15 |
| **Total Credits of the Course** | 4 |  |

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| **Text Book:**  |
| 1. John Clark, Derek Allen Holton - A first look at graph theory, Allied Publishers, 1991.
2. Discrete Mathematics, Seymour Lipschutz (Tata McGraw Hill), 1997.
3. Chen Chuan Chong , Koh Khee Meng , Principles and Techniques in Combinatorics, World Scientific Publishing, 2007.
 |
| **References** |
| 1. Kenneth H. Rosen, Discrete Mathematics and Its Applications, International Edition, 2018.
2. G Shanker Rao , Discrete Mathematics Structures, New Age International (P) Ltd. 2013.
3. R. Balakrishnan, K. Ranganathan, Text book of Graph Theory, Springer, 2012.
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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)**Direct Instruction, Explicit Teaching, E-learning, interactive Instruction:, Active co-operative learning, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student/ Group representative |
| **Assessment Types** | **Mode of Assessment** 1. **Continuous Internal Assessment (CIA)**
	* Internal Test -20 marks
	* Assignment – Every student needs to write an assignment on a given topic based on the available published literature – 10 marks
	* Seminar Presentation – A topic needs to be presented and discussed with the class- 10 marks
2. **Semester End examination – 60 marks**
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|  | **MAHATMA GANDHI UNIVERSITY, KOTTAYAM** |
| **MS M 21 C06: ORDINARY DIFFERENTIAL EQUATIONS** |

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| --- | --- |
| School Name | School of Mathematics and Statistics |
| Programme | MSc Mathematics |
| Course Name  | Ordinary Differential Equations |
| Type of Course | Core |
| Course Code | MS M 21 C06 |
| Course Objectives | One of the aims of this course is to provide real-life examples of ODE together with other examples to convince the students the importance of mathematical analysis and linear algebra in the study of ODEs. The power of analysis will be visible in the existence-uniqueness theory etc., whereas linear algebra is used powerfully in the study of linear systems. Thus, students will also get motivation to study other subjects like analysis, geometry and algebra. |
| Semester  | First |
| Total Student Learning Time (SLT) | Learning Approach | Lecture | Tutorial | Practical | Others | Total LearningHours |
|  | Authentic learningCollaborative learning Independent learning | 75 | 20 | 0 | 25 | 120 |
| Pre-requisite |  Basics of Differentiation and Integration |

**COURSE OUTCOMES (CO)**

|  |  |  |  |
| --- | --- | --- | --- |
| **CO No.** | **Expected Course Outcome** | **Learning Domains**  | **PSO No.** |
| 1 | The students will have some sound knowledge of basic topics in ODE as in the objective and they understand the importance of studying DE theoretically.  | U/R/A  | 1,2 |
| 2 | It will prepare them to study advanced topics like qualitative and stability analysis of dynamical systems, bifurcation theory, chaos, and so on. | U/A | 1,2 |
| 3 | Learns some applications of Ordinary Differential Equations | U/A | 1,2 |
| 4 | Some special functions related to Ordinary Differential Equations | U/A | 1,2 |
| **\**Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** |

**COURSE CONTENT**

|  |  |  |  |
| --- | --- | --- | --- |
| **Module No** | **Module Content** | **CO** | **Hrs** |
| 1 | Physical Examples of ODE, Mathematical Examples to show lack of existence and Uniqueness, First Order Linear Equations, Integrating Factor, Exact Solutions, Second order linear equations, Solution Space, and its dimension, Second order with Constant coefficients, Methods-Variation of parameters | 1 | 20 |
| 2 | Existence and Uniqueness: Gronwall’s Lemma, Lipschitz continuity, Picard iteration method, Peano’s existence theorem, maximal interval of existence, estimates on the solution | 2 | 20 |
| 3. | Exponential of a matrix, Systems of linear equations and its representation via exponential of a matrix, stability analysis of 2X2 systems. Series Solution, Frobenius theory, Oscillations and the Sturm Separation Theorem, The Sturm Comparison Theorem | 3 | 20 |
| 4 | Bessel functions. The Gamma Function, Properties of Bessel functions. Additional Properties of Bessel Functions. Nonlinear equations: Autonomous systems, The Phase Plane and its Phenomena, Types of Critical points. Stability, Critical points and Stability for Linear Systems. | 4 | 15 |
| **Total Credits of the Course** | 4 |  |

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| **Text Book:**  |
| 1. George F. Simmons, Differential Equations with Applications and Historical Notes, Tata McGraw-Hill Second Edition 2003.
2. A. K. Nandakumaran, P.S. Datti, Raju George: Ordinary Differential Equations; Principles and Applications, Cambridge University Press, Cambridge-IISc Series 2017.
 |
| **References** |
| 1. Peter J. Collins, Differential and Integral Equations, Oxford University Press, (2006).
2. Carmen Chicone, Ordinary Differential Equations with Applications, Springer (2006).
3. Michael D. Greenberg, Ordinary Differential Equations, Wiley (2012).
4. Michael E. Taylor, Introduction to Differential Equations, AMS (2011).
5. Vladimir I. Arnol'd, Ordinary Differential Equations, Springer (1992).
6. Earl. A. Coddington, An Introduction to Ordinary Differential Equations, Dover Publications, New York, (1961).
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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)**Direct Instruction, Explicit Teaching, E-learning, interactive Instruction:, Active co-operative learning, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student/ Group representative |
| **Assessment Types** | **Mode of Assessment** 1. **Continuous Internal Assessment (CIA)**
	* Internal Test -20 marks
	* Assignment – Every student needs to write an assignment on a given topic based on the available published literature – 10 marks
	* Seminar Presentation – A topic needs to be presented and discussed with the class- 10 marks
2. **Semester End examination – 60 marks**
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**SECOND SEMESTER COURSES**

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| **Course code** | **Name of the Course** | **Teaching hrs** | **Credits** |
| MS M 21 C07 | ALGEBRA –II | 4 +1+0 | 4 |
| MS M 21 C08 | REAL ANALYSIS- II | 4 +1+0 | 4 |
| MS M 21 C09 | COMPLEX ANALYSIS | 4 +1+0 | 4 |
| MS M 21 C10 | FUNCTIONAL ANALYSIS | 4 +1+0 | 4 |
|  | ELECTIVE 1 | 4 +1+0 | 4 |
|  | ELECTIVE 2 | 4 +1+0 | 4 |
|  | **TOTAL CREDITS** |  | **24** |

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|  | **MAHATMA GANDHI UNIVERSITY, KOTTAYAM** |
| **MS M 21 C07: ALGEBRA-II** |

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| School Name | School of Mathematics and Statistics |
| Programme | MSc Mathematics |
| Course Name  | Algebra II |
| Type of Course | Core |
| Course Code | MS M 21 C07 |
| Course Objectives | To introduce important notions such as field extensions, finite fields, splitting fields, Galois theory etc. |
| Semester  | Second |
| Total Student Learning Time (SLT) | Learning Approach | Lecture | Tutorial | Practical | Others | Total LearningHours |
|  | Authentic learningCollaborative learning Independent learning | 75 | 20 | 0 | 25 | 120 |
| Pre-requisite |  Basics of Abstract Algebra |

**COURSE OUTCOMES (CO)**

|  |  |  |  |
| --- | --- | --- | --- |
| **CO No.** | **Expected Course Outcome** | **Learning Domains**  | **PSO No.** |
| 1 | The students will get a basic idea of field theory, which has many applications in advanced algebra, algebraic coding theory etc. | U/R/A  | 1,2 |
| 2 | Basic knowledge about Unique factorization domains | U/A | 1,2 |
| 3 | Basic knowledge about splitting fields | U/A | 1,2 |
| 4 | Basic idea of Galois Theory and applications | U/A | 1,2 |
| **\**Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** |

**COURSE CONTENT**

|  |  |  |  |
| --- | --- | --- | --- |
| **Module No** | **Module Content** | **CO** | **Hrs** |
| 1 | Introduction to extension fields, algebraic extensions, Geometric Constructions Finite fields.(Part VI – Section 29, 31 – 31.1 to 31.18, 32, 33 of the text) | 1 | 20 |
| 2 | Unique factorization domains, Euclidean domains. Gaussian integers and multiplicative norms(Part IX – Sections 45, 46 & 47 of the text) | 2 | 20 |
| 3. | Automorphism of fields, the isomorphism extension theorem, Splitting fields. (Part X – Sections 48 & 49, 50 of the text) | 3 | 15 |
| 4 | Separable extensions, Galois Theory, Illustrations of Galois Theory, Cyclotomic Extensions. (mention the insolvability of the quintic) (Part X – Sections 51, 53, 54, 55 - 55.1 to 55.6 of the text) | 4 | 20 |
| **Total Credits of the Course** | 4 |  |

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| **Text Book:**  |
| 1. John B. Fraleigh, A First Course in Abstract Algebra, 7thedition, Pearson Education
 |
| **References** |
| 1. Algebra - M. Artin, Second Edition, Pearson.
2. Contemporary Abstract Algebra - J. A. Gallian, 4th Edition, Narosa.
3. Topics in Algebra - I.N. Herstein, Second Edition, Wiley Student Edition.
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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)**Direct Instruction, Explicit Teaching, E-learning, interactive Instruction:, Active co-operative learning, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student/ Group representative |
| **Assessment Types** | **Mode of Assessment** 1. **Continuous Internal Assessment (CIA)**
	* Internal Test -20 marks
	* Assignment – Every student needs to write an assignment on a given topic based on the available published literature – 10 marks
	* Seminar Presentation – A topic needs to be presented and discussed with the class- 10 marks
2. **Semester End examination – 60 marks**
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|  | **MAHATMA GANDHI UNIVERSITY, KOTTAYAM** |
| **MS M 21 C08: REAL ANALYSIS II** |

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| School Name | School of Mathematics and Statistics |
| Programme | MSc Mathematics |
| Course Name  | Real Analysis II |
| Type of Course | Core |
| Course Code | MS M 21 C08 |
| Course Objectives | To introduce the theory of measures and Lebesgue integration theory. This finds applications in Probability Theory. |
| Semester  | Second |
| Total Student Learning Time (SLT) | Learning Approach | Lecture | Tutorial | Practical | Others | Total LearningHours |
|  | Authentic learningCollaborative learning Independent learning | 75 | 20 | 0 | 25 | 120 |
| Pre-requisite |  Basics of Real Analysis |

**COURSE OUTCOMES (CO)**

|  |  |  |  |
| --- | --- | --- | --- |
| **CO No.** | **Expected Course Outcome** | **Learning Domains**  | **PSO No.** |
| 1 | A sound knowledge of Lebesgue measure and integration | U/R/A  | 1,2 |
| 2 | Applications classical theorems of measure theory and product measures. | U/A | 1,2 |
| 3 | Basic idea on Generation of measures | U/A | 1,2 |
| 4 | Applications of Decomposition of Measures, Product Measures | U/A | 1,2 |
| **\**Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** |

**COURSE CONTENT**

|  |  |  |  |
| --- | --- | --- | --- |
| **Module No** | **Module Content** | **CO** | **Hrs** |
| 1 | Introduction, Measurable Functions, Measures | 1 | 20 |
| 2 | The Integral, Integrable Functions, Lp-spaces. | 2 | 18 |
| 3. | Modes of Convergence, Generation of measures | 3 | 20 |
| 4 | Decomposition of Measures, Product Measures | 4 | 17 |
| **Total Credits of the Course** | 4 |  |

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| **Text Book:**  |
| 1. R.G. Bartle – The Elements of Integration and Lebesgue Measure John Wiley, 2014.
 |
| **References** |
| 1. H.L. Royden - Real Analysis, 1988.
2. G. De Barra - Measure theory and Integration, Van Nostrand 1974.
3. P.K.Jain - Lebesgue Measure and Integration, New Age International Publishers, 2017.
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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)**Direct Instruction, Explicit Teaching, E-learning, interactive Instruction:, Active co-operative learning, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student/ Group representative |
| **Assessment Types** | **Mode of Assessment** 1. **Continuous Internal Assessment (CIA)**
	* Internal Test -20 marks
	* Assignment – Every student needs to write an assignment on a given topic based on the available published literature – 10 marks
	* Seminar Presentation – A topic needs to be presented and discussed with the class- 10 marks
2. **Semester End examination – 60 marks**
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|  | **MAHATMA GANDHI UNIVERSITY, KOTTAYAM** |
| **MS M 21 C09: COMPLEX ANALYSIS** |

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| --- | --- |
| School Name | School of Mathematics and Statistics |
| Programme | MSc Mathematics |
| Course Name  | Complex Analysis |
| Type of Course | Core |
| Course Code | MS M 21 C09 |
| Course Objectives | * 1. To teach the fundamental properties of holomorphic functions, Cauchy theory, and power series expansions, and their applications to other areas of mathematics and science.
 |
| Semester  | Second |
| Total Student Learning Time (SLT) | Learning Approach | Lecture | Tutorial | Practical | Others | Total LearningHours |
|  | Authentic learningCollaborative learning Independent learning | 75 | 20 | 0 | 25 | 120 |
| Pre-requisite |  Basics of complex numbers |

**COURSE OUTCOMES (CO)**

|  |  |  |  |
| --- | --- | --- | --- |
| **CO No.** | **Expected Course Outcome** | **Learning Domains**  | **PSO No.** |
| 1 | * 1. Basic understanding on the definition and basic properties of holomorphic functions
 | U/R/A  | 1,2 |
| 2 | Ability to identify the convergence of power series | U/An | 1,2 |
| 3 | Ability to apply the Cauchy theory to a variety of problems. | U/A | 1,2 |
| 4 | Prepare the student for *advanced complex analysis* and *analytic number theory.* | U/An | 1,2 |
| **\**Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** |

**COURSE CONTENT**

|  |  |  |  |
| --- | --- | --- | --- |
| **Module No** | **Module Content** | **CO** | **Hrs** |
| 1 | Complex differentiability and holomorphy, and conformality (Chapter 1, sections 1,2,3, Chapter 2, sections 1,2). | 1 | 20 |
| 2 | Convergence of power series and their holomorphy (Chapter 4, sections 1, 2, 3), and elementary transcendental functions (Chapter 5, sections 1, 2, 3, 4). | 2 | 18 |
| 3. | Development of the Cauchy integral theorem (Chapter 6, sections 1,2,3 and Chapter 7, sections 1, 2, 3). | 3 | 20 |
| 4 | Identity theorem, open mapping theorem, maximum principle (Chapter 8, sections 1,5), general Cauchy theory (Chapter 9, section 5), meromorphic functions (Chapter 10, section 1), Laurent series (Chapter 12, section 1), the residue theorem (Chapter 13, sections 1,2). | 4 | 17 |
| **Total Credits of the Course** | 4 |  |

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| **Text Book:**  |
| 1. Reinhold Remmert , Theory of Complex Functions , Springer 1989.
 |
| **References** |
| 1. Lars Ahlfors , Complex Analysis, McGraw Hill, 1979.
2. Walter Rudin, Real and Complex Analysis, McGraw Hill, 1986.
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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)** Direct Instruction, Explicit Teaching, E-learning, interactive Instruction:, Active co-operative learning, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student/ Group representative |
| **Assessment Types** | **Mode of Assessment** 1. **Continuous Internal Assessment (CIA)**
	* Internal Test -20 marks
	* Assignment – Every student needs to write an assignment on a given topic based on the available published literature – 10 marks
	* Seminar Presentation – A topic needs to be presented and discussed with the class- 10 marks
2. **Semester End examination – 60 marks**
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|  | **MAHATMA GANDHI UNIVERSITY, KOTTAYAM** |
| **MS M 21 C10: FUNCTIONAL ANALYSIS** |

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| School Name | School of Mathematics and Statistics |
| Programme | MSc Mathematics |
| Course Name  | Functional Analysis |
| Type of Course | Core |
| Course Code | MS M 21 C10 |
| Course Objectives | To introduce some important notions such as normed spaces, linear operators, dual spaces, Hilbert spaces and different types of linear operators. |
| Semester  | Second |
| Total Student Learning Time (SLT) | Learning Approach | Lecture | Tutorial | Practical | Others | Total LearningHours |
|  | Authentic learningCollaborative learning Independent learning | 75 | 20 | 0 | 25 | 120 |
| Pre-requisite |  Real Analysis, Linear Algebra |

**COURSE OUTCOMES (CO)**

|  |  |  |  |
| --- | --- | --- | --- |
| **CO No.** | **Expected Course Outcome** | **Learning Domains**  | **PSO No.** |
| 1 | The students will understand basic concepts in functional analysis which has lot of applications in other branches of Mathematics. | U/R  | 1,2 |
| 2 | Basic knowledge about Inner product spaces | U/R  | 1,2 |
| 3 | An insight into some particular types of linear operators | U/R  | 1,2 |
| **\**Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** |

**COURSE CONTENT**

|  |  |  |  |
| --- | --- | --- | --- |
| **Module No** | **Module Content** | **CO** | **Hrs** |
| 1 | Examples, Completeness proofs, Completion of Metric Spaces, Vector Space, Normed Space, Banach space, Further Properties of Normed Spaces, Finite Dimensional Normed spaces and Subspaces, Compactness and Finite Dimension(Chapter 1 – Sections 1.5, 1.6; Chapter 2 - Sections 2.1 to 2.5) | 1 | 20 |
| 2 | Linear Operators, Bounded and Continuous Linear Operators, Linear Functionals, Linear Operators and Functionals on Finite dimensional spaces, Normed spaces of operators, Dual space(Chapter 2 - Section 2.6 to 2.10) | 1 | 17 |
| 3. | Inner Product Space, Hilbert space, Further properties of Inner Product Space, Orthogonal Complements and Direct Sums, Orthonormal sets and sequences, Series related to Orthonormal sequences and sets, Total Orthonormal sets and sequences, Representation of Functionals on Hilbert Spaces(Chapter 3 - Sections 3.1 to 3.6, 3.8) | 2 | 20 |
| 4 | Hilbert-Adjoint Operator, Self-Adjoint, Unitary and Normal Operators, Zorn’s lemma, Hahn- Banach theorem, Hahn- Banach theorem for Complex Vector Spaces and Normed Spaces, Adjoint Operators(Chapter 3 - Sections 3.9, 3.10; Chapter 4 - Sections 4.1 to 4.3, 4.5) | 3 | 18 |
| **Total Credits of the Course** | 4 |  |

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| **Text Book:**  |
| Erwin Kreyszig: Introductory Functional Analysis with Applications, John Wiley and Sons, New York. |
| **References** |
| 1. Rudin W., Functional Analysis, 2nd edition, McGraw-Hill, New York (1991).
2. Reed, M. and B. Simon, Methods of Mathematical Physics, vol. II, Academic Press, New York (1975).
3. Rajendra Bhatia, Notes on Functional Analysis, Texts and Readings in Mathematics, Hindusthan Book Agency, New Delhi (2009).
4. G. F. Simmons, Introduction to Topology and Modern Analysis, TMH.
5. M. Thamban Nair, Functional Analysis; A first course, PHI Learning Pvt. Ltd (2001).
6. S. Kesavan Functional Analysis Hindustan Book Agency, (TRIM 52)
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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)** Direct Instruction, Explicit Teaching, E-learning, interactive Instruction:, Active co-operative learning, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student/ Group representative |
| **Assessment Types** | **Mode of Assessment** 1. **Continuous Internal Assessment (CIA)**
	* Internal Test -20 marks
	* Assignment – Every student needs to write an assignment on a given topic based on the available published literature – 10 marks
	* Seminar Presentation – A topic needs to be presented and discussed with the class- 10 marks
2. **Semester End examination – 60 marks**
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**ELECTIVE 1**

**ELECTIVE 2**

**THIRD SEMESTER COURSES**

|  |  |  |  |
| --- | --- | --- | --- |
| **Course code** | **NAME OF THE COURSE** | **Teaching hrs** | **Credits** |
| MS M 21 C11 | MULTIVARIABLE CALCULUS & GEOMETRY | 4 +1+0 | 4 |
| MS M 21 C12 | ANALYTIC NUMBER THEORY | 4 +1+0 | 4 |
| MS M 21 C13 | PROBABILITY THEORY | 4 +1+0 | 4 |
|  | ELECTIVE 3 | 4 +1+0 | 4 |
|  | ELECTIVE 4 | 4 +1+0 | 4 |
|  | OPEN COURSE |  | 4 |
|  | **TOTAL CREDITS** |  | **24** |

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|  | **MAHATMA GANDHI UNIVERSITY, KOTTAYAM** |
| **MS M 21 C11: MULTIVARIABLE CALCULUS AND GEOMETRY** |

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| School Name | School of Mathematics and Statistics |
| Programme | MSc Mathematics |
| Course Name  | Multivariable Calculus and Geometry |
| Type of Course | Core |
| Course Code | MS M 21 C11 |
| Course Objectives | Aim of this course is to provide a good understanding on calculus of several variables, geometry of curves and surfaces. |
| Semester  | Third |
| Total Student Learning Time (SLT) | Learning Approach | Lecture | Tutorial | Practical | Others | Total LearningHours |
|  | Authentic learningCollaborative learning Independent learning | 75 | 20 | 0 | 25 | 120 |
| Pre-requisite |  Differentiation and Integration  |

**COURSE OUTCOMES (CO)**

|  |  |  |  |
| --- | --- | --- | --- |
| **CO No.** | **Expected Course Outcome** | **Learning Domains**  | **PSO No.** |
| 1 | Attains good knowledge in calculus of several variables, geometry of curves and surfaces.  | U/R  | 1,2 |
| 2 | Equip them for taking up advanced courses in the area of geometry and analysis. | U | 1,2 |
| 3 | Attains a good knowledge on applications of multivariable calculus | U/A | 1,2 |
| **\**Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** |

**COURSE CONTENT**

|  |  |  |  |
| --- | --- | --- | --- |
| **Module No** | **Module Content** | **CO** | **Hrs** |
| 1 | Directional derivative, Directional derivatives and continuity, Total derivative, Total derivative expressed in terms of partial derivatives, The matrix of a linear function, The Jacobian matrix, The Chain rule, The matrix form of the chain rule.[Chapter 12 – Sections 12.1-12.10 (omit 12.6) from Text – 1] | 1,3 | 20 |
| 2 | The Mean-Value theorem for differentiable functions, A sufficient condition for differentiability, A sufficient condition for equality of mixed partial derivatives, Functions with non-zero Jacobian determinant, The inverse function theorem, The implicit function theorem.[Chapter 12 – Sections 12.11-12.13, Chapter 13- Sections 13.1 – 13.4 from Text – 1] | 1,3 | 18 |
| 3. | What is a curve? Arc-length, Re parametrization, Closed curves, Level curves versus parametrized curves. Curvature, Plane curves, Space curves. What is a surface, Smooth surfaces, Smooth maps, Tangents and derivatives, Normals and Orientability.[Chapter 1 – Sections 1- 5, Chapter 2 – Sections 1 – 3, Chapter 4 – Sections 1 – 5 from Text - 2]. | 1,2,3 | 20 |
| 4 | Applications of the inverse function theorem, Lengths of curves on surfaces, The second fundamental form, The Gauss and Weingarten maps, Normal and geodesic curvatures. Parallel Transport and Covariant Derivative, Gaussian and mean curvatures, Principal curvatures of a surface. [Chapter 5 – Section 6, Chapter 6 – Sections 1, Chapter 7 – Sections 1 – 4, Chapter 8 – Sections 1 – 2 from Text - 2]. | 1,2,3 | 17 |
| **Total Credits of the Course** | 4 |  |

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| **Text Book:**  |
| 1. T.M. Apostol, Mathematical Analysis, 2ndEdn. Addison-Wesley, 1986.
2. Andrew Pressley, Elementary Differential Geometry, 2nd Edn. Springer 2010.
 |
| **References** |
| 1. W Rudin - Principles of Mathematical Analysis, (3rd edn) Mc. Graw- Hill, 1986.
2. J.R. Munkres - Analysis on Manifolds, Westview Press, 1997.
3. Michael Spivak - Calculus on Manifolds, Westview Press, 1971.
4. C.C. Pugh - Real Mathematical Analysis, Springer, 2010.
5. M. Spivak - A Comprehensive Introduction to Differential Geometry, Vol. 1, Publish or Perish, Boston, 1970.
6. W Klingenberg - A course in Differential Geometry.
7. M.P. do Carmo - Differential Geometry of Curves and Surfaces
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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)** Direct Instruction, Explicit Teaching, E-learning, interactive Instruction:, Active co-operative learning, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student/ Group representative |
| **Assessment Types** | **Mode of Assessment** 1. **Continuous Internal Assessment (CIA)**
	* Internal Test -20 marks
	* Assignment – Every student needs to write an assignment on a given topic based on the available published literature – 10 marks
	* Seminar Presentation – A topic needs to be presented and discussed with the class- 10 marks
2. **Semester End examination – 60 marks**
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|  | **MAHATMA GANDHI UNIVERSITY, KOTTAYAM** |
| **MS M 21 C12: ANALYTIC NUMBER THEORY** |

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| School Name | School of Mathematics and Statistics |
| Programme | MSc Mathematics |
| Course Name  | Analytic Number Theory |
| Type of Course | Core |
| Course Code | MS M 21 C12 |
| Course Objectives | To introduce one of the very fascinating areas of Mathematics which has wide ranging applications. |
| Semester  | Third |
| Total Student Learning Time (SLT) | Learning Approach | Lecture | Tutorial | Practical | Others | Total LearningHours |
|  | Authentic learningCollaborative learning Independent learning | 75 | 20 | 0 | 25 | 120 |
| Pre-requisite |  Theory of Numbers  |

**COURSE OUTCOMES (CO)**

|  |  |  |  |
| --- | --- | --- | --- |
| **CO No.** | **Expected Course Outcome** | **Learning Domains**  | **PSO No.** |
| 1 | Attains good knowledge in various types of arithmetic functions  | U/R  | 1,2 |
| 2 | Develops a critical knowledgesome Elementary Theorems on the Distribution of Prime Numbers | U/A | 1,2 |
| 3 | Able to analyze congruences  | U/A | 1,2 |
| 4 | Understand the concepts of quadratic residues and primitive roots | U/A | 1,2 |
| **\**Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** |

**COURSE CONTENT**

|  |  |  |  |
| --- | --- | --- | --- |
| **Module No** | **Module Content** | **CO** | **Hrs** |
| 1 | Arithmetic Functions, Dirichlet Multiplication and Averages of Arithmetical functions Arithmetic Functions, Dirichlet Multiplication: Introduction, The Möbius function μ(n),The Euler totient function ϕ(n), a relation connecting μ and ϕ, a product formula for ϕ(n),The Dirichlet product of arithmetical functions, Dirichlet inverses and the Möbius inversion formula, The Mangoldt function ∧(n),Multiplicative functions, Multiplicative functions and Dirichlet Multiplication, The inverse of a completely multiplicative function, The Liouville’s function λ(n), The divisor function 𝜎𝛼(n), Generalized convolutions**Averages of Arithmetical functions:** Introduction, The big oh notation, Asymptotic equality of functions, Eulers summation formula, Some elementary asymptotic formulas, The average order of d(n),The average order of the divisor functions 𝜎𝛼(n),The average order of ϕ(n),An application to the distribution of lattice points visible from the origin,The average order of μ(n) and of ∧(n),The partial sums of a Dirichlet product, Applications to μ(n) and of∧(n).(Chapter 2: sections 2.1 to 2.14, Chapter 3:3.1 to 3.11) | 1 | 20 |
| 2 | Some Elementary Theorems on the Distribution of Prime Numbers Introduction, Chebyshev’s functions ψ(x) and ϑ(x), Relation connecting ϑ(x) and π(x),Some equivalent forms of the prime number theorem, Inequalities for π(n) and Pn, Shapiro’s tauberian theorem, Applications of Shapiro’stheorem, An asymptotic formula for the partial sum 𝑝≤𝑥(chapter 4: sections 4.1 to 4.8) | 2 | 18 |
| 3. | Congruences: Definitions and basic properties of congruences, Residue classes and complete residue system, Linear congruences, Reduced residue systems and Euler-Fermat theorem, Polynomial congruences modulo p, Lagrange’s theorem, Applications of Lagrange’s theorem, Simultaneous linear congruences, The Chinese remainder theorem, Applications of the Chinese remainder theorem.(Chapter 5: 5.1to5.8) | 3 | 17 |
| 4 | Quadratic Residues, The Quadratic Reciprocity Law and Primitive Roots, Quadratic Residues, The Quadratic Reciprocity Law: Quadratic residues, Legendre’s symbol and its properties, evaluation of (-1|p) and (2|p),Gauss’ Lemma, The quadratic reciprocity law, Applications of the reciprocity lawPrimitive Roots: The exponent of a number mod m, Primitive roots, Primitive roots and reduced residue systems, The nonexistence of primitive roots mod 2𝛼for 𝛼≥3,The existence of primitive root mod p for odd primes p, Primitive roots and quadratic residues..(Chapter 9; 9.1 to 9.6)(Chapter 10: 10.1to10.5) | 4 | 20 |
| **Total Credits of the Course** | 4 |  |

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| **Text Book:**  |
| T. M. Apostol, Introduction to Analytic Number Theory, Springer International Student Edition, Narosa |
| **References** |
| 1. G. H. Hardy and E. M. Wright – An Introduction to Theory of Numbers, Oxford University Press, 1979, 5th Ed.,
2. I. Niven, H. S. Zuckerman and H. L. Montgomery – An Introduction to the Theory of Numbers, New York, John Wiley and Sons, Inc., 2004, 5th Ed.,
3. GarethA.Jones , [JosephineM. Jones](https://www.amazon.in/s/ref%3Ddp_byline_sr_ebooks_2?ie=UTF8&field-author=Josephine+M.+Jones&text=Josephine+M.+Jones&sort=relevancerank&search-alias=digital-text), Elementary Number Theory (Springer Undergraduate Mathematics Series) Kindle Edition.
4. David M. Burton, Elementary Number Theory.
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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)** Direct Instruction, Explicit Teaching, E-learning, interactive Instruction:, Active co-operative learning, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student/ Group representative |
| **Assessment Types** | **Mode of Assessment** 1. **Continuous Internal Assessment (CIA)**
	* Internal Test -20 marks
	* Assignment – Every student needs to write an assignment on a given topic based on the available published literature – 10 marks
	* Seminar Presentation – A topic needs to be presented and discussed with the class- 10 marks
2. **Semester End examination – 60 marks**
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|  | **MAHATMA GANDHI UNIVERSITY, KOTTAYAM** |
| **MS M 21 C13: PROBABILITY THEORY** |

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| School Name | School of Mathematics and Statistics |
| Programme | MSc Mathematics |
| Course Name  | Probability Theory |
| Type of Course | Core |
| Course Code | MS M 21 C12 |
| Course Objectives | This is designed as a first course on Probability Theory which is mathematically rigorous. The aim is to expose the students to basics notions and theorems of Probability theory. They can see how the abstract field of measure theory gets used to model random events of real life. This course lays the mathematical foundation for a student interested in pursuing applications of probability theory in various fields such as Statistics. |
| Semester  | Third |
| Total Student Learning Time (SLT) | Learning Approach | Lecture | Tutorial | Practical | Others | Total LearningHours |
|  | Authentic learningCollaborative learning Independent learning | 75 | 20 | 0 | 25 | 120 |
| Pre-requisite | Basics of Statistics |

**COURSE OUTCOMES (CO)**

|  |  |  |  |
| --- | --- | --- | --- |
| **CO No.** | **Expected Course Outcome** | **Learning Domains**  | **PSO No.** |
| 1 | Through knowledge about probabilistic notions such as random variables, independence, expectation etc.  | U/R  | 1,2 |
| 2 | Able to compute distributions and expectations of random variables using integration theory. | U/A | 1,2 |
| 3 | A basic understanding of law of large numbers  | U/A | 1,2 |
| 4 | A basic understanding of the central limit theorem | U/A | 1,2 |
| **\**Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** |

**COURSE CONTENT**

|  |  |  |  |
| --- | --- | --- | --- |
| **Module No** | **Module Content** | **CO** | **Hrs** |
| 1 | Probability Spaces – Dynkin’s theorem, Construction of Probability Spaces, Measure Construction. Random variables, Elements and Measurable maps – Inverse maps, Measurable Maps, Random Elements, Measurability and Continuity, Sigma fields generated by maps (Chapters 2 & 3 of text book 1) | 1 | 20 |
| 2 | Independence – Records, ranks and Renyi’s theorem, Groupings, Borel-Cantellilemma, 0-1 laws integration and expectation – Transformation theorem and densities, product spaces, independence and Fubini’s Theorem (Chapters 4 & 5 [except 5.6] of text book 1) | 2 | 18 |
| 3. | Convergence – A.S., convergence in probability, Lp convergence. Laws of large numbers and sums of independent random variables – Truncation and equivalence, General Weak Law of Large Numbers, Almost sure convergence of sums of independent random variables, Strong law of large numbers for iid sequences, applications, Kolmogorov Three Series Theorem, (Chapters 6 & 7 [except 6.4, 6.6 and Section 7.6.1] of text book 1) | 3 | 17 |
| 4 | Convergence in distribution – Scheffe’s Lemma, Baby Skorohod Theorem, Relations among modes of convergence. Characteristic Functions and CLT – MGF and CLT, Expansions, Moments and Derivatives, Uniqueness and Continuity, Classical CLT for iidrvs, Lindeberg-Feller CLT (8.1, 8.2 [except 8.2.1], 8.3, 8.5 of text book 1, All section of Chapter 9 [except proofs of results in section 9.6.1, 9.6.2 & 9.6.3] of text book 1) | 4 | 20 |
| **Total Credits of the Course** | 4 |  |

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| **Text Book:**  |
| S.I. Resnick, A Probability Path , Birkhauser (1999) |
| **References** |
| 1. A.K. Basu – Probability Theory, Prentice Hall India 2002.
2. P. Billingsley – Probability, John Wiley (1968), (Reprint) 2000.
3. K.L. Chung – Elementary Probability Theory, Narosa.
4. W. Feller – Introduction to Probability Theory and Applications Vols. I & II, John Wiley

5. V.S. Borkar – Probability Theory, Springer 1995 |

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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)** Direct Instruction, Explicit Teaching, E-learning, interactive Instruction:, Active co-operative learning, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student/ Group representative |
| **Assessment Types** | **Mode of Assessment** 1. **Continuous Internal Assessment (CIA)**
	* Internal Test -20 marks
	* Assignment – Every student needs to write an assignment on a given topic based on the available published literature – 10 marks
	* Seminar Presentation – A topic needs to be presented and discussed with the class- 10 marks
2. **Semester End examination – 60 marks**
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**ELECTIVE 3**

**ELECTIVE 4**

 **OPEN COURSE**

**FOURTH SEMESTER COURSES**

 **TOTAL CREDITS-16**

|  |
| --- |
| **SEMESTER IV Total Credits 16** |
| **Course Code** | **Name of Course** | **L+T+P** | **Credits** |
|  | ELECTIVE 5 | 4+1+0 | 4 |
| MS M 21 C14 | PROJECT WORK / DISSERTATION | 20 | 12 |
|  | Total Credits |  | 16 |

**Elective 5**

**MS M 21 C14 PROJECT WORK/ DISSERTATION**

**DETAILED SYLLABI OF ELECTIVES**

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|  | **MAHATMA GANDHI UNIVERSITY, KOTTAYAM** |
| **MS M21E01: PARTIAL DIFFERENTIAL EQUATIONS**  |

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| --- | --- |
| School Name | School of Mathematics and Statistics |
| Programme | MSc Mathematics |
| Course Name  | Partial Differential Equations |
| Type of Course | Elective |
| Course Code | **MS M21E01** |
| Course Objectives | Here we wish to introduce PDE as a topic of analysis. Quite often, this topic is introduced as an artificially created problem solving subject making an impression that this topic is not interesting. The main aim is to change this wrong notion among the community. Through the method of characteristics, analysis of Laplace, Poisson, heat and wave equations, we see the beautiful derivation of results using geometry and analysis. Again, motivating the students to study other subjects like analysis, geometry, algebra in a realistic way than these are abstract objects. |
| Semester  | ----- |
| Total Student Learning Time (SLT) | Learning Approach | Lecture | Tutorial | Practical | Others | Total LearningHours |
|  | Authentic learningCollaborative learning Independent learning | 75 | 20 | 0 | 25 | 120 |
| Pre-requisite | Calculus, ODE |

**COURSE OUTCOMES (CO)**

|  |  |  |  |
| --- | --- | --- | --- |
| **CO No.** | **Expected Course Outcome** | **Learning Domains**  | **PSO No.** |
| 1 | The students will have some sound knowledge of basic classical topics in PDE as in the objective  | U/R  | 1,2 |
| 2 | Understand the importance of studying PDE theoretically.  | U/A | 1,2 |
| 3 | The modern and advanced PDE is rather different and this will a background for them to pursue the modern PDE in a non-classical way. | U/A | 1,2 |
| **\**Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** |

**COURSE CONTENT**

|  |  |  |  |
| --- | --- | --- | --- |
| **Module No** | **Module Content** | **CO** | **Hrs** |
| 1 | First order PDE; Method of Characteristics, Linear, Quasi linear and fully non-linear equations in two independent variables, Classification of PDE in two variables. | 1,2,3 | 20 |
| 2 | Laplacian and Poisson equations, Mean Value property, Maximum principles, Uniqueness theorem | 1,2,34 | 15 |
| 3. | Heat equation and its derivation one dimension, Maximum and minimum principle, Heat equation in finite interval and Fourier method. | 1,2,3 | 20 |
| 4 | One dimensional Wave equation, homogeneous and non-homogeneous equation, Duhamel’s principle, characteristic parallelogram. Two- and three-dimensional wave equation, method of spherical means in three-dimensional wave equation, method of descent to two-dimensional wave equation. | 1,2,3 | 20 |
| **Total Credits of the Course** | 4 |  |

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| **Text Book:**  |
| 1. A.K. Nandakumaran and P.S. Datti, Partial Differential Equations; Classical theory with a modern touch, Cambridge University Press, Cambridge-IISc Series 2020.
2. L.C. Evans, Partial Differential Equations, Rhode Island, AMS, Providence, 1998.
3. Y. Pinchover and Rubinstein, An introduction to Partial Differential Equations, Cambridge University Press (2005).
 |
| **References** |
| 1. F. John, Partial Differential Equations, 3rd Ed., New-York, Springer-Verlag (1978).
2. G. B Folland, Introduction to Partial Differential Equations, Princeton University Press (1995).
3. M. Renardy and R. C. Rogers, Partial Differential Equations, New-York, Springer (2004).
4. Phoolan Prasad and Renuka Ravindran, Partial Differential Equations, New age international, 1985.
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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)** Direct Instruction, Explicit Teaching, E-learning, interactive Instruction:, Active co-operative learning, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student/ Group representative |
| **Assessment Types** | **Mode of Assessment** 1. **Continuous Internal Assessment (CIA)**
	* Internal Test -20 marks
	* Assignment – Every student needs to write an assignment on a given topic based on the available published literature – 10 marks
	* Seminar Presentation – A topic needs to be presented and discussed with the class- 10 marks
2. **Semester End examination – 60 marks**
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|  | **MAHATMA GANDHI UNIVERSITY, KOTTAYAM** |
| **MS M21E02: DIFFERENTIAL GEOMETRY** |

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| School Name | School of Mathematics and Statistics |
| Programme | MSc Mathematics |
| Course Name  | Differential Geometry |
| Type of Course | Elective |
| Course Code | **MS M21E02** |
| Course Objectives | Aim of this course is to provide a good understanding of the vector calculus on Rn, smooth manifolds, tangent and cotangent vectors, sub manifolds and differential forms on manifolds. |
| Semester  | ----- |
| Total Student Learning Time (SLT) | Learning Approach | Lecture | Tutorial | Practical | Others | Total LearningHours |
|  | Authentic learningCollaborative learning Independent learning | 75 | 20 | 0 | 25 | 120 |
| Pre-requisite | Basic Knowledge in algebra, analysis, topology, calculus etc. |

**COURSE OUTCOMES (CO)**

|  |  |  |  |
| --- | --- | --- | --- |
| **CO No.** | **Expected Course Outcome** | **Learning Domains**  | **PSO No.** |
| 1 | Attains good knowledge in vector calculus on Rn, smooth manifolds, tangent and cotangent vectors, sub manifolds and differential forms on manifolds. | U/R  | 1,2 |
| 2 | Further this course will equip them for taking up in-depth study in the area of differential geometry and its applications | U/A | 1,2 |
| **\**Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** |

**COURSE CONTENT**

|  |  |  |  |
| --- | --- | --- | --- |
| **Module No** | **Module Content** | **CO** | **Hrs** |
| 1 | Vector Fields: An Introduction, Gradient, Divergence, Curl, and the Del Operator (omit Other Coordinate Formulations), Scalar and Vector Line Integrals (omit numerical evaluation of line integrals), Green’s Theorem, Parametrized Surfaces, Surface Integrals, Stokes’s and Gauss’s Theorems (proof may be omitted). (Chapter 3: Sections-3.3, 3.4, Chapter 6: Sections 6.1, 6.2, Chapter 7: Sections-7.1, 7.2, 7.3 from text 1) | 1,2 | 20 |
| 2 | Topological manifolds, Examples of topological manifolds, Smooth structures, Examples of smooth manifolds, Smooth functions and smooth maps, Diffeomorphisms, Lie groups, Proper maps, Partition of Unity.Tangent vectors, Pushforwards, Computations in coordinates (omit tangent space to manifolds with boundary)Chapter 1: Sections 1-4, Chapter 2: Sections 1, 2, 4, 5, Chapter 3: Sections 1-3 from text 2) | 1,2 | 15 |
| 3. | Tangent vectors to curves. The tangent bundle, Vector fields on manifolds, Covectors, Tangent convectors on manifolds, The cotangent bundle.Differential of a function, Pullbacks, Line integrals, Maps of constant rank, Constant rank maps between manifolds, Submersions, Embedded submanifolds. (Chapter 3: Section 4, Chapter 4: Sections 1-2, Chapter 6: Sections 1-6, Chapter 7: Sections 1, 4, Chapter 8: Section 1 from text 2) | 1,2 | 20 |
| 4 | Tensors, The algebra of tensors, Tensors and tensor fields on manifolds, Riemannian metrics (upto the Riemannian distance function), Differential Forms, The geometry of volume measurement, Algebra of alternating tensors, The wedge product, Differential forms on manifolds. Exterior derivative.(Chapter 11: Sections 1-4, Chapter 12: Sections 1-5 from text 2 ) | 1,2 | 20 |
| **Total Credits of the Course** | 4 |  |

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| **Text Book:**  |
| 1. Susan Jane Colley - Vector Calculus, Pearson, 2012.
2. John M. Lee - Introduction to Smooth Manifolds, Springer.
 |
| **References** |
| 1. Spivak M - A comprehensive introduction to differential geometry (Vol. 1).
2. Frank Warner - Foundations of differentiable manifolds and Lie groups, Springer, 1971.
3. Jeffrey M. Lee - Manifolds and Differential Geometry, Graduate studies in Mathematics, Vol 107, AMS, 2009.
4. Marcel Berger - A Panoramic View of Riemannian Geometry, Springer, 2002.
5. Yozo Matsushima - Differentiable Manifolds, Marcel Dekker, 1972.
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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)** Direct Instruction, Explicit Teaching, E-learning, interactive Instruction:, Active co-operative learning, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student/ Group representative |
| **Assessment Types** | **Mode of Assessment** 1. **Continuous Internal Assessment (CIA)**
	* Internal Test -20 marks
	* Assignment – Every student needs to write an assignment on a given topic based on the available published literature – 10 marks
	* Seminar Presentation – A topic needs to be presented and discussed with the class- 10 marks
2. **Semester End examination – 60 marks**
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|  | **MAHATMA GANDHI UNIVERSITY, KOTTAYAM** |
| **MS M21E03 : ALGEBRAIC TOPOLOGY** |

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| School Name | School of Mathematics and Statistics |
| Programme | MSc Mathematics |
| Course Name  | Algebraic Topology |
| Type of Course | Elective |
| Course Code | **MS M21E03** |
| Course Objectives | Aim of this course is to provide a good understanding of the most important functors of algebraic topology, the fundamental group, of a topological space and Simplicial and singular homology and computation of homology.  |
| Semester  | ----- |
| Total Student Learning Time (SLT) | Learning Approach | Lecture | Tutorial | Practical | Others | Total LearningHours |
|  | Authentic learningCollaborative learning Independent learning | 75 | 20 | 0 | 25 | 120 |
| Pre-requisite | Knowledge in Algebra and Topology |

**COURSE OUTCOMES (CO)**

|  |  |  |  |
| --- | --- | --- | --- |
| **CO No.** | **Expected Course Outcome** | **Learning Domains**  | **PSO No.** |
| 1 | Students will attain good knowledge in the fundamental group of a topological space, Simplicial and singular homology, and computation of homology.  | U/R  | 1,2 |
| 2 | Further this course will equip them for taking up in-depth study in the area of algebraic topology and applications. | U/A | 1,2 |
| **\**Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** |

**COURSE CONTENT**

|  |  |  |  |
| --- | --- | --- | --- |
| **Module No** | **Module Content** | **CO** | **Hrs** |
| 1 | The Fundamental Group, Basic Constructions, Paths and Homotopy, The Fundamental Group of the Circle, Induced Homomorphisms, Van Kampen’s Theorem, Free Products of Groups, The van Kampen Theorem. | 1,2 | 20 |
| 2 | Applications to Cell Complexes. Covering Spaces, Lifting Properties, The Classification of Covering Spaces, Deck Transformations and Group Actions. | 1,2 | 15 |
| 3. | Simplicial and Singular Homology, Simplicial Homology, Singular Homology, Homotopy Invariance, Exact Sequences and Excision, The Equivalence of Simplicial and Singular Homology | 1,2 | 20 |
| 4 | Computations and Applications, Degree, Cellular Homology, Mayer-Vietoris Sequences, Homology with Coefficients | 1,2 | 20 |
| **Total Credits of the Course** | 4 |  |

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| **Text Book:**  |
| Allen Hatcher - Algebraic Topology, 2001. |
| **References** |
| 1. Munkers - Elements of Algebraic Topology
2. William S. Massey - Algebraic Topology : An Introduction.
3. A Dold, Lectures on Algebraic Topology – Springer, 1995.
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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)** Direct Instruction, Explicit Teaching, E-learning, interactive Instruction:, Active co-operative learning, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student/ Group representative |
| **Assessment Types** | **Mode of Assessment** 1. **Continuous Internal Assessment (CIA)**
	* Internal Test -20 marks
	* Assignment – Every student needs to write an assignment on a given topic based on the available published literature – 10 marks
	* Seminar Presentation – A topic needs to be presented and discussed with the class- 10 marks
2. **Semester End examination – 60 marks**
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|  | **MAHATMA GANDHI UNIVERSITY, KOTTAYAM** |
| **MS M21E04 : ADVANCED FUNCTIONAL ANALYSIS** |

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| --- | --- |
| School Name | School of Mathematics and Statistics |
| Programme | MSc Mathematics |
| Course Name  | Advanced Functional Analysis |
| Type of Course | Elective |
| Course Code | **MS M21E04** |
| Course Objectives | The objective is to have an intensive study of advanced topics in Functional Analysis. |
| Semester  | ----- |
| Total Student Learning Time (SLT) | Learning Approach | Lecture | Tutorial | Practical | Others | Total LearningHours |
|  | Authentic learningCollaborative learning Independent learning | 75 | 20 | 0 | 25 | 120 |
| Pre-requisite | Basic Knowledge in Functionla Analysis |

**COURSE OUTCOMES (CO)**

|  |  |  |  |
| --- | --- | --- | --- |
| **CO No.** | **Expected Course Outcome** | **Learning Domains**  | **PSO No.** |
| 1 | Understand and apply fundamental theorems from the theory of normed spaces, including the Uniform Boundedness theorem, the open mapping theorem, the closed graph theorem, and the Banach Fixed Point theorem. | U/R  | 1,2 |
| 2 | The learners will be able to appreciate how functional analysis uses and unifies ideas from normed spaces and complex analysis. | U/A | 1,2 |
| 3 | Understand the fundamentals of spectral theory and appreciate its power. | U/R | 1,2 |
| 4 | Have a good grasp of the spectral properties of various operators such as Compact Linear Operators, Self-adjoint linear operators, Positive Operators and Projection Operators. | U/An/A | 1,2 |
| **\**Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** |

**COURSE CONTENT**

|  |  |  |  |
| --- | --- | --- | --- |
| **Module No** | **Module Content** | **CO** | **Hrs** |
| 1 | Reflexive Spaces, Category theorem(statement only), Uniform Boundedness theorem (applications excluded), Strong and Weak Convergence, Convergence of Sequences of Operators and Functionals, Open Mapping Theorem, Closed Linear Operators, Closed Graph Theorem(Chapter 4: Sections 4.6 to 4.9, 4.12, 4.13) | 1,2 | 20 |
| 2 | Banach Fixed point theorem, Spectral theory in Finite Dimensional Normed Spaces, Basic Concepts, Spectral Properties of Bounded Linear Operators, Further Properties of Resolvent and Spectrum, Use of Complex Analysis in Spectral Theory(Chapter 5: Section 5.1; Chapter 7: Sections 7.1 to 7.5) | 1,2 | 15 |
| 3. | Banach Algebras, Further Properties of Banach Algebras, Compact Linear Operators on Normed spaces, Further Properties of Compact Linear Operators, Spectral Properties of compact Linear Operators on Normed spaces, Further Spectral Properties of Compact Linear Operators(Chapter 7: Sections 7.6, 7.7; Chapter 8: Sections 8.1 to 8.4) | 1,2 | 20 |
| 4 | Spectral Properties of Bounded Self adjoint linear operators, Further Spectral Properties of Bounded Self Adjoint Linear Operators, Positive Operators, Projection Operators, Further Properties of Projections(Chapter 9: Sections 9.1 to 9.3, 9.5, 9.6) | 1,2 | 20 |
| **Total Credits of the Course** | 4 |  |

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| **Text Book:**  |
| Erwin Kreyszig, Introductory Functional Analysis with applications, John Wiley and sons, New York |
| **References** |
| 1. Rudin W., Functional Analysis, 2nd edition, McGraw-Hill, New York (1991).
2. Reed, M. and B. Simon, Methods of Mathematical Physics, vol. II, Academic Press, New York (1975).
3. Rajendra Bhatia, Notes on Functional Analysis, Texts and Readings in Mathematics, Hindusthan Book Agency, New Delhi (2009).
4. G. F. Simmons, Introduction to Topology and Modern Analysis, TMH.
5. M. Thamban Nair, Functional Analysis; A first course, PHI Learning Pvt. Ltd (2001).
6. S. Kesavan Functional Analysis Hindustan Book Agency, (TRIM 52)
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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)** Direct Instruction, Explicit Teaching, E-learning, interactive Instruction:, Active co-operative learning, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student/ Group representative |
| **Assessment Types** | **Mode of Assessment** 1. **Continuous Internal Assessment (CIA)**
	* Internal Test -20 marks
	* Assignment – Every student needs to write an assignment on a given topic based on the available published literature – 10 marks
	* Seminar Presentation – A topic needs to be presented and discussed with the class- 10 marks
2. **Semester End examination – 60 marks**
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|  | **MAHATMA GANDHI UNIVERSITY, KOTTAYAM** |
| **: MS M21E05 ADVANCED COMPLEX ANALYSIS** |

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| School Name | School of Mathematics and Statistics |
| Programme | MSc Mathematics |
| Course Name  | Advanced Complex Analysis |
| Type of Course | Elective |
| Course Code | **MS M21E05** |
| Course Objectives | To introduce the theory of harmonic functions, Riemann zeta function, and the classical Riemann mapping theorem. |
| Semester  | ----- |
| Total Student Learning Time (SLT) | Learning Approach | Lecture | Tutorial | Practical | Others | Total LearningHours |
|  | Authentic learningCollaborative learning Independent learning | 75 | 20 | 0 | 25 | 120 |
| Pre-requisite | Basics of Complex analysis |

**COURSE OUTCOMES (CO)**

|  |  |  |  |
| --- | --- | --- | --- |
| **CO No.** | **Expected Course Outcome** | **Learning Domains**  | **PSO No.** |
| 1 | The students will study the classical notions of Mathematics such as infinite products, power series representations, Dirichlet problem and doubly periodic function. | U/R | 1,2 |
| 2 | A basic knowledge about the Riemann Zeta Function and related topics  | U/An |  |
| 3 | A basic knowledge about the Riemann Mapping Theorem & The Weierstrass’s Theorem | U/A |  |
| **\**Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** |

**COURSE CONTENT**

|  |  |  |  |
| --- | --- | --- | --- |
| **Module No** | **Module Content** | **CO** | **Hrs** |
| 1 | Harmonic Functions – Definitions and Basic Properties, The Mean-Value Property, Poisson’s Formula, Schwarz’s Theorem, The Reflection Principle. A closer look at Harmonic Functions – Functions with Mean Value Property, Harnack’s Principle. The Dirichlet’s Problem – Subharmonic Functions, Solution of Dirichlet’s Problem (Proof of Dirichlet’s Problem and Proofs of Lemma 1 and 2 excluded)(Chapter 4: Section 6: 6.1 - 6.5, Chapter 6: Section 3: 3.1 - 3.2, Section 4: 4.1 - 4.2) | 1 | 20 |
| 2 | Power Series Expansions – Weierstrass’s theorem, The Taylor Series, The Laurent Series, Partial Fractions and Factorization – Partial Fractions, Infinite Products, Canonical Products, The Gamma Function. Entire Functions – Jensen’s Formula, Hadamard’s Theorem (Hadamard’s theorem - proof excluded)(Chapter 5: Section 1: 1.1 - 1.3, Section 2: 2.1 – 2.4, Section 3: 3.1 – 3.2)  | 1 | 20 |
| 3. | The Riemann Zeta Function – The Product Development, The Extension of to the Whole Plane, The Functional Equation, The Zeroes of the Zeta Function Normal Families – Normality and Compactness, Arzela’s Theorem(Chapter 5: Section 4: 4.1 – 4.4, Section 5: 5.2 - 5.3) | 1,2 | 20 |
| 4 | The Riemann Mapping Theorem – Statement and Proof, Boundary Behaviour, Use of the Reflection Principle. The Weierstrass’s Theory–The Weierstrass’s - function, The functions (*s*) and (*z*) , The Differential Equation.(Chapter 6: Section 1: 1.1 – 1.3, Chapter 7: Section 3: 3.1 - 3.3) | 1,3 | 15 |
| **Total Credits of the Course** | 4 |  |

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| **Text Book:**  |
| Complex Analysis – Lars V. Ahlfors (Third Edition), McGraw Hill Book Company |
| **References** |
| 1. H. Cartan: Elementary Theory of analytic functions of one or several variables; Addison - Wesley Pub. Co.; 1973.
2. T.W. Gamelin: Complex Analysis; Springer-Verlag, NY Inc.; 2001
3. T.O. Moore and E.H. Hadlock: Complex Analysis, Series in Pure Mathematics-Vol. 9; World Scientific; 1991
4. L. Pennisi: Elements of Complex Variables (2nd Edn.); Holf, Rinehart & Winston; 1976
5. R. Remmert: Theory of Complex Functions; UTM , Springer-Verlag, NY; 1991
6. W. Rudin: Real and Complex Analysis (3rd Edn.); McGraw - Hill International Editions; 1987
7. H. Sliverman: Complex Variables; Houghton Mifflin Co. Boston; 1975
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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)** Direct Instruction, Explicit Teaching, E-learning, interactive Instruction:, Active co-operative learning, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student/ Group representative |
| **Assessment Types** | **Mode of Assessment** 1. **Continuous Internal Assessment (CIA)**
	* Internal Test -20 marks
	* Assignment – Every student needs to write an assignment on a given topic based on the available published literature – 10 marks
	* Seminar Presentation – A topic needs to be presented and discussed with the class- 10 marks
2. **Semester End examination – 60 marks**
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|  | **MAHATMA GANDHI UNIVERSITY, KOTTAYAM** |
|  **MS M21E06: CODING THEORY** |

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| School Name | School of Mathematics and Statistics |
| Programme | MSc Mathematics |
| Course Name  | Coding Theory |
| Type of Course | Elective |
| Course Code | **MS M21E06** |
| Course Objectives | To introduce one of the most exciting applications of Linear algebra and field theory in information theory. |
| Semester  | ----- |
| Total Student Learning Time (SLT) | Learning Approach | Lecture | Tutorial | Practical | Others | Total LearningHours |
|  | Authentic learningCollaborative learning Independent learning | 75 | 20 | 0 | 25 | 120 |
| Pre-requisite | Basics of Number Theory and Abstract Algebra |

**COURSE OUTCOMES (CO)**

|  |  |  |  |
| --- | --- | --- | --- |
| **CO No.** | **Expected Course Outcome** | **Learning Domains**  | **PSO No.** |
| 1 | The students will be exposed to the algebraic coding theory.  | U/R  | 1,2 |
| 2 | Linear codes, perfect codes, cyclic linear codes will also be introduced. | U/R |  |
| 3 | Student will acquire an idea on applications of Golay code & Cyclic linear codes | U/A |  |
| **\**Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** |

**COURSE CONTENT**

|  |  |  |  |
| --- | --- | --- | --- |
| **Module No** | **Module Content** | **CO** | **Hrs** |
| 1 | Detecting and correcting error patterns, Information rate, The effects of error detection and correction, Finding the most likely code word transmitted, Weight and distance, MLD, Error detecting and Correcting codes.  | 1 | 20 |
| 2 | Linear codes, bases for C = <S> and C┴, generating and parity check matrices, Equivalent codes, Distance of a linear code, MLD for a linear code, Reliability of IMLD for linear codes. Perfect codes, Hamming code, Extended codes, | 2 | 20 |
| 3. | Golay code and extended Golay code, Read Muller Codes. | 3 | 15 |
| 4 | Cyclic linear codes, Polynomial encoding and decoding, Dual cyclic codes. BCH Codes, Cyclic Hamming Code, Decoding 2 error correcting BCH codes. | 3 | 20 |
| **Total Credits of the Course** | 4 |  |

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| **Text Book:**  |
| Hoffman D.J et.al., Coding Theory - The Essentials*,* Published by Marcel Dekker Inc, 1991. |
| **References** |
| 1. Berlekamp E.R, Algebraic Coding Theory*,* McGraw-Hill, 1968
2. Cameron P.J and Van Lint J.H, Graphs*,* Codes and Designs, CUP, 1980
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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)** Direct Instruction, Explicit Teaching, E-learning, interactive Instruction:, Active co-operative learning, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student/ Group representative |
| **Assessment Types** | **Mode of Assessment** 1. **Continuous Internal Assessment (CIA)**
	* Internal Test -20 marks
	* Assignment – Every student needs to write an assignment on a given topic based on the available published literature – 10 marks
	* Seminar Presentation – A topic needs to be presented and discussed with the class- 10 marks
2. **Semester End examination – 60 marks**
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|  | **MAHATMA GANDHI UNIVERSITY, KOTTAYAM** |
| **MS M21E07 : ALGEBRAIC NUMBER THEORY** |

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| --- | --- |
| School Name | School of Mathematics and Statistics |
| Programme | MSc Mathematics |
| Course Name  | Algebraic Number Theory |
| Type of Course | Elective |
| Course Code | **MS M21E07** |
| Course Objectives | Expose to the algebraic Number theory. |
| Semester  | ----- |
| Total Student Learning Time (SLT) | Learning Approach | Lecture | Tutorial | Practical | Others | Total LearningHours |
|  | Authentic learningCollaborative learning Independent learning | 75 | 20 | 0 | 25 | 120 |
| Pre-requisite | Basics of Number Theory |

**COURSE OUTCOMES (CO)**

|  |  |  |  |
| --- | --- | --- | --- |
| **CO No.** | **Expected Course Outcome** | **Learning Domains**  | **PSO No.** |
| 1 | The students will be exposed to the algebraic Number theory.  | U/R  | 1,2 |
| **\**Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** |

**COURSE CONTENT**

|  |  |  |  |
| --- | --- | --- | --- |
| **Module No** | **Module Content** | **CO** | **Hrs** |
| 1 | Symmetric polynomials, Modules, Free abelian groups, Algebraic Numbers, Conjugates and Discriminants, Algebraic Integers, Integral Bases, Norms and Traces, Rings of Integers, Quadratic Fields, Cyclotomic Fields. (Chapter1: Sections 1.4 to 1.6; Chapter 2: Sections 2.1 to 2.6; Chapter 3, Sections 3.1 and 3.2 from the text) | 1 | 20 |
| 2 | Historical background, Trivial Factorizations, Factorization into Irreducibles, Examples of Nonunique Factorization into Irreducibles, Prime Factorization, Euclidean Domains, Eucidean Quadratic fields , Ideals , Historical background, Prime Factorization of Ideals, The norm of an ideal (Chapter 4: Sections 4.1 to 4.7, Chapter 5: Sections 5.1 to 5.3) | 1 | 20 |
| 3. | Lattices, The Quotient Torus, Minkowski theorem, The Space Lst, The Class-Group, An Existence Theorem, Finiteness of the Class-Group, Factorization of a Rational Prime, Fermats Last Theorem Some history.(Chapter 6, Chapter 7: Section 7.1 Chapter 8) | 1 | 20 |
| 4 | Elementary Considerations, Kummers Lemma, Kummers Theorem. (Chapter 9: Sections 9.1 to 9.3, Chapter 10: Section 10.1, Chapter 11: 11.1 to 11.4) | 1 | 15 |
| **Total Credits of the Course** | 4 |  |

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| **Text Book:**  |
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| **References** |
| 1. Karlheinz Spindler – Abstract Algebra with Applications, Vol. II, Rings and Fields, Marcel Dekker, Inc.
2. I. N. Stewart and David Tall – Algebraic Number Theory, Chapman and Hall.
3. Jody Esmonde and M. Ram Murthy – Problems in Algebraic Number Theory, Springer Verlag.
4. I. S. Luthar and I. B. S. Passi – Algebra Vol. II: Rings, Narosa Publishing House.
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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)** Direct Instruction, Explicit Teaching, E-learning, interactive Instruction:, Active co-operative learning, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student/ Group representative |
| **Assessment Types** | **Mode of Assessment** 1. **Continuous Internal Assessment (CIA)**
	* Internal Test -20 marks
	* Assignment – Every student needs to write an assignment on a given topic based on the available published literature – 10 marks
	* Seminar Presentation – A topic needs to be presented and discussed with the class- 10 marks
2. **Semester End examination – 60 marks**
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|  | **MAHATMA GANDHI UNIVERSITY, KOTTAYAM** |
| **MS M21E08: WAVELETS** |

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| School Name | School of Mathematics and Statistics |
| Programme | MSc Mathematics |
| Course Name  | Wavelets |
| Type of Course | Elective |
| Course Code | **MS M21E08** |
| Course Objectives | To introduce one of the recent transform techniques used in applied signal processing and off late in epidemiology. |
| Total Student Learning Time (SLT) | Learning Approach | Lecture | Tutorial | Practical | Others | Total LearningHours |
|  | Authentic learningCollaborative learning Independent learning | 75 | 20 | 0 | 25 | 120 |
| Pre-requisite | Basics of Number Theory and Abstract Algebra |

**COURSE OUTCOMES (CO)**

|  |  |  |  |
| --- | --- | --- | --- |
| **CO No.** | **Expected Course Outcome** | **Learning Domains**  | **PSO No.** |
| 1 | The students will learn, discrete Fourier transforms, construction of wavelets and multi resolution analysis. | U/R  | 1,2 |
| **\**Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** |

**COURSE CONTENT**

|  |  |  |  |
| --- | --- | --- | --- |
| **Module No** | **Module Content** | **CO** | **Hrs** |
| 1 | The Discrete Fourier Transform, Translation-Invariant Linear Transformations, First Stage Construction of Wavelets on ZN. | 1 | 20 |
| 2 | Construction of Wavelets on ZN : Iteration step, Examples and Applications, l2(Z), Complete Orthonormal Sets in Hilbert Spaces, | 1 | 20 |
| 3. | L2([ ; )) and Fourier Series, The Fourier Transform and Convolution on l2(Z) , First-Stage Wavelets on Z; The Iteration step for Wavelets on Z; Implementation and Examples. | 1 | 15 |
| 4 | L2(R) and approximate Identities, The Fourier Transform on R; Multiresolution Analysis and Wavelets. | 1 | 20 |
| **Total Credits of the Course** | 4 |  |

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| **Text Book:**  |
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| **References** |
| 1. Charles K. Chui, An Introduction to Wavelets, Academic (1992).
2. Ingrid Daubechies, Ten Lectures on Wavelets, SIAM, (1992).
3. K.R Unni, Wavelets, Frames and Wavelet Bases in LP Lecture notes, Bhopal (1997).
4. Stephane Mallat, A Wavelet Tour Of Signal Processing, Academic Press (1999).
5. Don Hong, Jianzhong Wang, Robert Gardner, Real Analysis with an Introduction to Wavelets, Elsevier Academic Press (2005).
6. Yves Meyer, Wavelets and Operators, Cambridge University Press (1992).
7. John. J Beneditto, Michael W. Frazier Wavelets-Mathematics and Applications, CRC, (1994).
8. Eugenio Hernandez, Guido L. Weiss, First course on wavelets, CRC, (1996).
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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)** Direct Instruction, Explicit Teaching, E-learning, interactive Instruction:, Active co-operative learning, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student/ Group representative |
| **Assessment Types** | **Mode of Assessment** 1. **Continuous Internal Assessment (CIA)**
	* Internal Test -20 marks
	* Assignment – Every student needs to write an assignment on a given topic based on the available published literature – 10 marks
	* Seminar Presentation – A topic needs to be presented and discussed with the class- 10 marks
2. **Semester End examination – 60 marks**
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|  | **MAHATMA GANDHI UNIVERSITY, KOTTAYAM** |
| **MS M21E09 : GRAPHS AND MATRICES** |

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| --- | --- |
| School Name | School of Mathematics and Statistics |
| Programme | MSc Mathematics |
| Course Name  | Graphs and Matrices |
| Type of Course | Elective |
| Course Code | **MS M21E09** |
| Course Objectives | To teach fundamentals of graph theory. More on algebraic graph theory. |
| Semester  | ----- |
| Total Student Learning Time (SLT) | Learning Approach | Lecture | Tutorial | Practical | Others | Total LearningHours |
|  | Authentic learningCollaborative learning Independent learning | 75 | 20 | 0 | 25 | 120 |
| Pre-requisite | Basics of Graph Theory |

**COURSE OUTCOMES (CO)**

|  |  |  |  |
| --- | --- | --- | --- |
| **CO No.** | **Expected Course Outcome** | **Learning Domains**  | **PSO No.** |
| 1 | The students will learn basic notions such as matchings, connectivity etc which has wide ranging applications. | U/R  | 1,2 |
| 2 | Familiarize with the applications of Linear algebra and matrices in mathematical chemistry and Google search. | U/R | 1,2 |
| **\**Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** |

**COURSE CONTENT**

|  |  |  |  |
| --- | --- | --- | --- |
| **Module No** | **Module Content** | **CO** | **Hrs** |
| 1 | Fundamental concepts, Graphs as Models, Matrices and Isomorphisms, Decompositions and Special Graphs, Paths, Cycles and Trails, Bipartite Graphs, Eulerian Circuits, Vertex Degrees and counting, Graphic Sequences, Trees, Distance in Trees, Matchings, Independent sets and Covers(**Text 1**Chapter 1: Sections 1.1.1 – 1.1.5, 1.1.7 - 1.1.42, 1.2.2 –1.2.21, 1.2.24 – 1.2.27, 1.3.1 – 1.3.18, 1.3.27 – 1.3.30 , Chapter 2: Sections 2.1.1. –2.1.13 , Chapter 3: 3.1.1 – 3.1.13, 3.1.18 – 3.1.24, 3.1.25 – 3.1.29) | 1 | 20 |
| 2 | Cuts and connectivity, Blocks, k-connected graphs, Coloring of graphs, Brooke’s theorem, Planar Graphs**(**Chapter 4: Sections 4.1.1 – 4.1.11, 4.1.16 – 4.1.19, 4.2.1 – 4.2.8 , Chapter 5: Sections 5.1.1 – 5.1.11, 5.1.22Chapter 6: Sections 6.1.1 – 6.1.28 Text 1) | 1 | 20 |
| 3. | Adjacency MatrixEigenvalues of some graphs, Determinant, Bounds, Energy of a graph, Antiadjacency matrix of a directed graph, Lemma 3.32 - Nonsingular trees .Laplacian MatrixBasic properties, Computing Laplacianeigenvalues, Matrix-tree theorem, Theorem 4.12 - Bounds for Laplacian spectral radius**(**Chapter 3: Sections 3.1 – 3.5, 3.6 – Lemma 3.32 - Nonsingular trees, Chapter 4: Sections 4.1-4.4 of Text 2) | 2 | 15 |
| 4 | Regular Graphs:- Perron–Frobenius theory, Adjacency algebra of a regular graph, Complement and line graph of a regular graph, Strongly regular graphs and friendship theoremDistance Matrix of a Tree:- Distance matrix of a graph, Distance matrix and Laplacian of a tree(Chapter 6: Sections 6.1-6.4, Chapter 9: sections 9.1-9.2 of Text 2) | 2 | 20 |
| **Total Credits of the Course** | 4 |  |

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| **Text Book:**  |
| 1. Douglas B West , Introduction to Graph Theory (Prentice Hall 2001 Second Ed.).2. R.B. Bapat , Graphs and Matrices (Springer 2014) |
| **References** |
| 1. R. Balakrishnan and K. Ranganathan , A Text book of Graph Theory, Second edition Springer
2. John Clark and Derek Allan Holton, A First Look at Graph Theory, Allied Publishers
3. Andries E. Brouwer, Willem H. Haemers, Spectra of Graphs, Monograph
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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)** Direct Instruction, Explicit Teaching, E-learning, interactive Instruction:, Active co-operative learning, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student/ Group representative |
| **Assessment Types** | **Mode of Assessment** 1. **Continuous Internal Assessment (CIA)**
	* Internal Test -20 marks
	* Assignment – Every student needs to write an assignment on a given topic based on the available published literature – 10 marks
	* Seminar Presentation – A topic needs to be presented and discussed with the class- 10 marks
2. **Semester End examination – 60 marks**
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|  | **MAHATMA GANDHI UNIVERSITY, KOTTAYAM** |
| **MS M21 E10: REPRESENTATION THEORY** |

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| School Name | School of Mathematics and Statistics |
| Programme | MSc Mathematics |
| Course Name  | Representation Theory |
| Type of Course | Elective |
| Course Code | **MS M21E10**  |
| Course Objectives | To teach the fundamental results on representations and characters of finite and compact groups in a complex vector space. |
| Semester  | ----- |
| Total Student Learning Time (SLT) | Learning Approach | Lecture | Tutorial | Practical | Others | Total LearningHours |
| Authentic learningCollaborative learning Independent learning | 75 | 20 | 0 | 25 | 120 |
| Pre-requisite | ---- |

**COURSE OUTCOMES (CO)**

|  |  |  |  |
| --- | --- | --- | --- |
| **CO No.** | **Expected Course Outcome** | **Learning Domains**  | **PSO No.** |
| 1 | The student will understand the classification of irreducible representations of finite and compact groups using their characters,  | U/R  | 1,2 |
| 2 | The student will understand Schur-orthogonality relations and the construction of representations using induction | U/R | 1,2 |
| **\**Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** |

**COURSE CONTENT**

|  |  |  |  |
| --- | --- | --- | --- |
| **Module No** | **Module Content** | **CO** | **Hrs** |
| 1 | **Generalities on linear representations:** Definitions, basic examples, sub representations, irreducible representations, tensor products, symmetric square and alternating square (Chapter 1 of the textbook) | 1 | 20 |
| 2 | * + 1. **Character Theory:** Characters, Schur’s lemma, orthogonality relations, decomposition of the regular representation, number of irreducible representations, canonical decomposition of a representation, explicity decomposition of a representation (Chapter 2).
 | 1 | 20 |
| 3. | * + 1. **Subgroups, products, induced representations:** Abelian subgroups, product of two subgroups, induced representations (Chapter 3).
 | 2 | 15 |
| 4 | **Compact Groups:** Compact groups, invariant measure on a compact group, linear representations of compact groups (Chapter 3), a choice of examples (to be chosen by each student and presented, using one of the examples in Chapter 4 or other references). | 2 | 20 |
| **Total Credits of the Course** | 4 |  |

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| **Text Book:**  |
| Jean-Pierre Serre *,* Linear Representations of Finite Group, Springer, 1977. |
| **References** |
| 1. William Fulton andJoe Harris, Representation theory: A First Course, Springer 1991.
2. Amritanshu Prasad, Representation Theory: A Combinatorial Viewpoint, Cambridge University Press, 2015.
3. J. L. Alperin and Rowen B. Bell , Groups and Representations, Springer, 1995.
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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)** Direct Instruction, Explicit Teaching, E-learning, interactive Instruction:, Active co-operative learning, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student/ Group representative |
| **Assessment Types** | **Mode of Assessment** 1. **Continuous Internal Assessment (CIA)**
	* Internal Test -20 marks
	* Assignment – Every student needs to write an assignment on a given topic based on the available published literature – 10 marks
	* Seminar Presentation – A topic needs to be presented and discussed with the class- 10 marks
2. **Semester End examination – 60 marks**
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|  | **MAHATMA GANDHI UNIVERSITY, KOTTAYAM** |
| **MS M21E11: LINEAR PROGRAMMING** |

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| School Name | School of Mathematics and Statistics |
| Programme | MSc Mathematics |
| Course Name  | Linear Programming |
| Type of Course | Elective |
| Course Code |  **MS M21E11** |
| Course Objectives | To impart a sound understanding of the theory as well as practice of linear programming and its applications to operations research, other branches of mathematics, and computer science. |
| Semester  | ----- |
| Total Student Learning Time (SLT) | Learning Approach | Lecture | Tutorial | Practical | Others | Total LearningHours |
|  | Authentic learningCollaborative learning Independent learning | 75 | 20 | 0 | 25 | 120 |
| Pre-requisite | ---- |

**COURSE OUTCOMES (CO)**

|  |  |  |  |
| --- | --- | --- | --- |
| **CO No.** | **Expected Course Outcome** | **Learning Domains**  | **PSO No.** |
| 1 | The student will be able to formulate optimization problems as linear programs and solve them using the simplex method.  | U/R  | 1,2 |
| 2 | The student will understand the theoretical underpinnings of linear programming with various pivot rules, why they work and their computational efficiency. | U/R | 1,2 |
| **\**Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** |

**COURSE CONTENT**

|  |  |  |  |
| --- | --- | --- | --- |
| **Module No** | **Module Content** | **CO** | **Hrs** |
| 1 | The simplex method, pitfalls, efficiency, duality, Gaussian elimination (Chapters 1-6). | 1 | 20 |
| 2 | * + 1. Revised simplex method, solution of general LP problems, duality and feasibility, sensitivity (Chapters 7 to 10), selecred applications (students may choose and present).
 | 1 | 20 |
| 3. | * + 1. Network flow problems, the network simplex method, upper-bounded transshipment problems, maximum flows, the primal-dual method (Chapters 19-23).
 | 2 | 15 |
| 4 | Advanced techniques: updating a triangular factorization of the basis, generalized upper bounding, the Dantzig-Wolfe decomposition principle (Chapters 24-26). | 2 | 20 |
| **Total Credits of the Course** | 4 |  |

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| **Text Book:**  |
|  Linear Programming, by Vašek Chvatál, Freeman, 1983. |
| **References** |
| 1. Understanding and Using Linear Programming, by JiříMatoušek and Bernd Gärtner, Univesitext, Springer, 2007.
2. Operations Research: A Practical Introduction, by Michael W. Carter, Camille C. Price, and Ghaith Rabadi (2nd Edition), CRC Press, 2019.
3. Ravindran A, Philips D.T and Soleberg J.J. (1997) Operation Research-Principles and Practice, John Wiley & Sons.
4. Linear Programming: Foundations and Extensions, by Robert J. Vanderbei (5th Edition), Springer, 2020.
5. Flows in Networks, L. R. Ford Jr. and D. R. Fulkerson, Princeton University Press, 2011.
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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)** Direct Instruction, Explicit Teaching, E-learning, interactive Instruction:, Active co-operative learning, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student/ Group representative |
| **Assessment Types** | **Mode of Assessment** 1. **Continuous Internal Assessment (CIA)**
	* Internal Test -20 marks
	* Assignment – Every student needs to write an assignment on a given topic based on the available published literature – 10 marks
	* Seminar Presentation – A topic needs to be presented and discussed with the class- 10 marks
2. **Semester End examination – 60 marks**
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|  | **MAHATMA GANDHI UNIVERSITY, KOTTAYAM** |
| **MS M21E12 : CRYPTOGRAPHY** |

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| School Name | School of Mathematics and Statistics |
| Programme | MSc Mathematics |
| Course Name  | Cryptography |
| Type of Course | Elective |
| Course Code | **MS M21E12** |
| Course Objectives | To teach one of the recent exciting topic which finds lot of applications in secret communication. |
| Semester  | ----- |
| Total Student Learning Time (SLT) | Learning Approach | Lecture | Tutorial | Practical | Others | Total LearningHours |
|  | Authentic learningCollaborative learning Independent learning | 75 | 20 | 0 | 25 | 120 |
| Pre-requisite | ---- |

**COURSE OUTCOMES (CO)**

|  |  |  |  |
| --- | --- | --- | --- |
| **CO No.** | **Expected Course Outcome** | **Learning Domains**  | **PSO No.** |
| 1 | The students will be introduced to classical cryptography | U/R  | 1,2 |
| **\**Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** |

**COURSE CONTENT**

|  |  |  |  |
| --- | --- | --- | --- |
| **Module No** | **Module Content** | **CO** | **Hrs** |
| 1 | Symmetric,Asymmetric,Monoalphabetic,Caesar,Affine, polyalphabetic, Vigenere, Hill, Permutation, Cryptanalysis of affine cipher, Shannon’s perfect secrecy, Vernamcipher(Onetimepad), Randomness, pseudo-random generators, Pseudo-random functions. (Chapter3, 4 of 1) | 1 | 20 |
| 2 | Blockcipher, Stream Cipher, Block ciphermodes of operation, feistelnet- work, DES, Toy example, 3 DES, Substitution permutation (SP) network, S-box, AES. (Chapter 5, 6 of 1) | 1 | 20 |
| 3. | Integer Factorization, Discrete logarithm, RSA, Diffie Hellman, El Gamal cryptosystems, Factoring techniques, Baby step-Giant step algorithm, Elliptic Curves, Elliptic curve variant of RSA, El Gamal.(Chapter 8, 9 of 1) | 2 | 15 |
| 4 | Hash, SHA-I, SHA-256, Message Authentication Code (MAC), Digital Signatures, Types of Digital signatures, Elliptic Curve variants of digital signatures, Secret Sharing.(Chapter 11, 12, 15 of 1) | 2 | 20 |
| **Total Credits of the Course** | 4 |  |

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| **Text Book:**  |
| Johannes Buchmann. Introduction to cryptography. Springer Science & Business Media, 2013. |
| **References** |
| 1. Jeffrey Hoffstein, Jill Pipher, Joseph H Silverman, and Joseph H Silverman. An introduction to mathematical cryptography, volume1. Springer, 2008.
2. Jonathan Katz and Yehuda Lindell. Introduction to modern cryptography. CRC press, 2014.
3. Josef Pieprzyk, Thomas Hardjono, and Jennifer Seberry. Fundamentals of computer security. Springer Science & Business Media, 2013.
4. William Stallings. Cryptography and network security, 4/E. Pearson Education India, 2006.
5. Douglas Robert Stinson and Maura Paterson. Cryptography: theory and practice. CRC press, 2018.
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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)** Direct Instruction, Explicit Teaching, E-learning, interactive Instruction:, Active co-operative learning, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student/ Group representative |
| **Assessment Types** | **Mode of Assessment** 1. **Continuous Internal Assessment (CIA)**
	* Internal Test -20 marks
	* Assignment – Every student needs to write an assignment on a given topic based on the available published literature – 10 marks
	* Seminar Presentation – A topic needs to be presented and discussed with the class- 10 marks
2. **Semester End examination – 60 marks**
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|  | **MAHATMA GANDHI UNIVERSITY, KOTTAYAM** |
| **MS M21E13: OPERATIONS RESEARCH** |

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| School Name | School of Mathematics and Statistics |
| Programme | MSc Mathematics |
| Course Name  | Operations Research |
| Type of Course | Elective |
| Course Code | MSM21E13 |
| Course Objectives | To make the students able to deal with optimization problems and the mathematical theory involved in them. |
| Semester  | ----- |
| Total Student Learning Time (SLT) | Learning Approach | Lecture | Tutorial | Practical | Others | Total LearningHours |
|  | Authentic learningCollaborative learning Independent learning | 75 | 20 | 0 | 25 | 120 |
| Pre-requisite | ---- |

**COURSE OUTCOMES (CO)**

|  |  |  |  |
| --- | --- | --- | --- |
| **CO No.** | **Expected Course Outcome** | **Learning Domains**  | **PSO No.** |
| 1 | Students are able to make use of various OR techniques such as LPP, Transportation problems, Assignment and Sequencing, Dynamic and Quadratic Programing, NLPP, Inventory Management, Game Theory etc for the efficient functioning of the firm or industry. | U/R  | 1,2 |
| **\**Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** |

**COURSE CONTENT**

|  |  |  |  |
| --- | --- | --- | --- |
| **Module No** | **Module Content** | **CO** | **Hrs** |
| 1 | **1.1** Linear programming: convex sets and associated theorems, **1.2** Simplex method, Artificial variables technique-Big M method,**1.3** Two phase method; Dual simplex method. Concept and theorems of duality, **1.4** Transportation problems, Assignment problems, **1.5** Sequencing, Traveling sales man problems. | 1 | 20 |
| 2 | **2.1** Dynamic and Quadratic programming: Bellman’s principle of optimality, single additive constraint- additively separable return,**2.2** single multiplicative constraint- additively separable return, single additive constraint-multiplicatively separable return, **2.3** General non-linear programming problem, Constrained optimization with equality constraints -necessary conditions for a general NLPP, sufficient conditions for a general NLPP with one constraint, sufficient conditions for a general problem with *m*(<*n*)constraints,**2.4** Constrained optimization with inequality constraints, Kuhn-Tucker conditions for general NLPP with *m*(<*n*) constraints, **2.5** Wolfe’s modified simplex method and Beale’s method. | 1 | 20 |
| 3. | **3.1** Inventory models:-Deterministic inventory models - general inventory model,**3.2** Economic-order quantity (EOQ) models -classic EOQ model, EOQ with price breaks, multi-item EOQ with storage limitation, **3.3** Probabilistic inventory models:- Single period stochastic models without setup cost, General single period models. | 1 | 17 |
| 4 | **4.1** Theory of Games, Two person zero sum games, fundamental theorem of matrix games, **4.2** Rectangular games as a Linear programming problem, Dominance property, **4.3** Graphical Method of solution 2 x n and m x2 games. | 1 | 18 |
| **Total Credits of the Course** | 4 |  |

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| **Text Book:**  |
| 1. Kanti Swarup, Gupta, P.K. and Man Mohan (2001) Operations Research, Ninth edition, Sultan Chand & Sons
2. Sharma J.K. (2013) Operations Research: Theory and Applications, Fifth edition,Laxmi Publications-New Delhi.
3. Ravindran A, Philips D.T and Soleberg J.J. (1997) Operation Research-Principles and Practice, John Wiley & Sons.
 |
| **References** |
| 1. Taha H.A. (2007) Operations Research -An introduction, Eighth edition, Prentice-Hall of India Ltd.
2. Gass S.I. (1985) Linear Programming -methods and applications, Fifth edition, McGraw Hill, USA,
3. Sinha, S.M. (2006) Mathematical programming theory and methods, Elsevier, a division of Reed Elsevier India Pvt. Ltd., New Delhi.
4. Paneerselvam, R. (2008) Operations Research, Second edition, Prentice Hall of India Pvt. Ltd., New Delhi.
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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)** Direct Instruction, Explicit Teaching, E-learning, interactive Instruction:, Active co-operative learning, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student/ Group representative |
| **Assessment Types** | **Mode of Assessment** 1. **Continuous Internal Assessment (CIA)**
	* Internal Test -20 marks
	* Assignment – Every student needs to write an assignment on a given topic based on the available published literature – 10 marks
	* Seminar Presentation – A topic needs to be presented and discussed with the class- 10 marks
2. **Semester End examination – 60 marks**
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|  | **MAHATMA GANDHI UNIVERSITY, KOTTAYAM** |
| **MS M21E14 : DATA SCIENCE AND DATA ANALYTICS** |

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| School Name | School of Mathematics and Statistics |
| Programme | MSc Mathematics |
| Course Name  | Data Science and Data Analytics |
| Type of Course | Elective |
| Course Code | MSM21E14 |
| Course Objectives | To make students aware of basics of big data analytics and various statistical methods used for analyzing big data. They are to be trained in fundamentals of data warehousing and data mining for big data analysis. |
| Semester  | ----- |
| Total Student Learning Time (SLT) | Learning Approach | Lecture | Tutorial | Practical | Others | Total LearningHours |
|  | Authentic learningCollaborative learning Independent learning | 75 | 20 | 0 | 25 | 120 |
| Pre-requisite | ---- |

**COURSE OUTCOMES (CO)**

|  |  |  |  |
| --- | --- | --- | --- |
| **CO No.** | **Expected Course Outcome** | **Learning Domains**  | **PSO No.** |
| 1 | Students have understood basics of big data analytics and can pursue big data analysis using different softwares and statistical techniques. | U/R  | 1,2 |
| 2. | They are able to use Hadoop and MapReduce for processing big data sets. They can use these for machine earning, clustering and classification and can apply these in real data sets. | U/R  | 1,2 |
| **\**Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** |

**COURSE CONTENT**

|  |  |  |  |
| --- | --- | --- | --- |
| **Module No** | **Module Content** | **CO** | **Hrs** |
| 1 | **1.1** Origins of Data Science: Development, Popularization, Definition of Data Science, Professional Organizations, Case Study, Data Engineering, Acquiring, Ingesting, Transforming , Metadata, Storing and Retrieving . Big Data – Introduction, Data structures, Structuring Big Data, 1.2 Elements of Big data, Big Data analytics, 1.3 Big Data applications.1.4 Big Data in business context.Technologies for handling big data – Distributed and Parallel computing for Big Data.  | 1 | 20 |
| 2 | 2.1 Understanding Analytics, Drivers of Big data, Discovering Data, Data preparation, Data Conditioning, 2.2 Data Models, Computing Models, Model Building, Comparison of Reporting and Analysis, 2.3 Types of Analytics, Analytical approaches, Data Analytics Life Cycle, 2.4 Basic Data Analytic Methods using R, Descriptive Statistics, Exploratory Data Analysis, Visualization. | 1 | 20 |
| 3. | 3.1 Introducing Hadoop – HDFS and MapReduce., Hadoop Eco System, Hadoop Distributed file system, HDFS architecture. Hadoop YARN, 3.2 Introducing HBase, Hive and Pig, MapReduce framework, Techniques to Optimize MapReduce, Uses of MapReduce, 3.3 Role of HBase in Big data processing, Processing Data with MapReduce, Framework, 3.4 Developing simple MapReduce Application. MapReduce execution and implementing MapReduce Programs. | 2 | 17 |
| 4 | 4.1 YARN Architecture – Limitations of MapReduce, Advantages of YARN, 4.2 Working of YARN, YARN Schedulers, Configurations, Commands, Containers, 4.3 Introduction to Mahout – Machine Learning, Clustering, Classification, 4.4 Mahout Algorithms, Environment for Mahout. Introduction to NoSQL. | 2 | 18 |
| **Total Credits of the Course** | 4 |  |

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| **Text Book:**  |
| 1. Berson, A. and Smith, S.J. (1997): Data Warehousing, Data Mining, and OLAP. McGraw Hill Publishers.
2. Pujari, A.K. (2001) Data Mining Techniques, Universities Press.
3. Breiman, L. Friedman, J.H. Olshen, R.A. and Stone, C.J. (1984): Classification and Regression Trees. Wadsworth and Brooks/Cole
 |
| **References** |
| 1. EMC Services (2015) Data Science and Big Data Analytics:: Discovering, Analyzing, Visualizing and Presenting Data, Wiley, EMC Education Services
2. Davy Cielen, Arno D. B. Meysman, Mohamed Ali (2016) Introducing Data Science, , Manning Publications Co.
3. Han, J. and Kamber, M. (2012): Data Mining; Concepts and Techniques. 3rrd Edition Morgan Kaufmann Publishers.
4. Mitchell, T.M. (1997): Machine Learning. McGraw-Hill.
5. Ripley, B.D. (1996): Pattern Recognition and Neural Networks. Cambridge

University Press.1. Chuck Lam ( 2011) Hadoop in Action, Wiley India Pvt Ltd.
2. Jimmy Lin and Chris Dyer (2010) Data Intensive Text Processing with Map Reduce:, Morgan & Claypool Publishers.
3. Berry,M. and Linoff, G. (2000) Mastering Data Mining, John Wiley & Sons.
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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)** Direct Instruction, Explicit Teaching, E-learning, interactive Instruction:, Active co-operative learning, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student/ Group representative |
| **Assessment Types** | **Mode of Assessment** 1. **Continuous Internal Assessment (CIA)**
	* Internal Test -20 marks
	* Assignment – Every student needs to write an assignment on a given topic based on the available published literature – 10 marks
	* Seminar Presentation – A topic needs to be presented and discussed with the class- 10 marks
2. **Semester End examination – 60 marks**
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|  | **MAHATMA GANDHI UNIVERSITY, KOTTAYAM** |
| **MS M21E15: STOCHASTIC PROCESSES** |

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| School Name | School of Mathematics and Statistics |
| Programme | MSc Mathematics |
| Course Name  | Stochastic Processes |
| Type of Course | Elective |
| Course Code | MSM21E15 |
| Course Objectives | To impart basic knowledge & skills in Stochastic Models and their applications in Statistics. This is helpful in modeling natural phenomenon in everyday life. |
| Semester  | ----- |
| Total Student Learning Time (SLT) | Learning Approach | Lecture | Tutorial | Practical | Others | Total LearningHours |
|  | Authentic learningCollaborative learning Independent learning | 75 | 20 | 0 | 25 | 120 |
| Pre-requisite | ---- |

**COURSE OUTCOMES (CO)**

|  |  |  |  |
| --- | --- | --- | --- |
| **CO No.** | **Expected Course Outcome** | **Learning Domains**  | **PSO No.** |
| 1 | Students are familiar with various stochastic process modes  | U/R  | 1,2 |
| 2. | Able to apply these to model various data sets on income, population growth, epidemics, traffic, queues, etc. to derive valuable conclusions. | U/A  | 1,2 |
| **\**Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** |

**COURSE CONTENT**

|  |  |  |  |
| --- | --- | --- | --- |
| **Module No** | **Module Content** | **CO** | **Hrs** |
| 1 | **1.1** Introduction to stochastic processes:- classification of stochastic processes, wide sense and strict sense stationary processes, processes with stationary independent increments, **1.2** Markov process, Markov chains- transition probability matrices, Chapman-Kolmogorov equation, **1.3** first passage probabilities, generating function relations, criteria for recurrent and transient states, **1.4** Communication of states, Reducible and irreducible Markov chains, mean recurrence time, classification of states. | 1,2 | 20 |
| 2 | **2.1** Mean ergodic theorem, basic limit theorem of Markov chains (statement only), stationary distributions, limiting probabilities and absorption probabilities. **2.2** Random walk, gambler’s ruin problem; ultimate ruin probabilities, random walk approximation of Brownian motion and diffusion process **2.3** Galton-Watson branching process, generating function relations, mean and variance functions, **2.4** extinction probabilities, criteria for extinction, distribution of total progeny size. | 1,2 | 20 |
| 3. | **3.1** Continuous time Markov chains, Poisson processes, properties, inter-arrival time distribution **3.2** pure birth processes and the Yule processes, **3.3** birth and death processes, Kolmogorov forward and backward differential equations, linear growth process with immigration, **3.4**steady-state solutions of Markovian queues - M/M/1, M/M/s, M/M/∞ models. | 1,2 | 17 |
| 4 | **4.1** Renewal processes - concepts, examples, Poisson process viewed as a renewal process, renewal equation, **4.2** elementary renewal theorem, Key renewal theorem (statement only), applications, delayed renewal processes. **4.3** Time series modeling, Autocorrelation function (ACF), partial auto correlation function(PACF), correlogram, AR, MA, ARMA, ARIMA Models, **4.4** Yule- Walker equations, Box-Jenkins Model fitting and diagnostics.  | 1,2 | 18 |
| **Total Credits of the Course** | 4 |  |

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| **Text Book:**  |
| 1. Karlin S. and Taylor H.M. (1975) A First Course in Stochastic Processes, Second Edition, Academic Press, New-York.
2. Medhi J. (2017) Stochastic Processes, Second Edition , Wiley Eastern, New Delhi
3. Ross S.M. (2007) Stochastic Processes. Second Edition, Wiley Eastern, New Delhi
 |
| **References** |
| 1. Brockwell P.J and Davis R.A. (2002) Introduction to Time Series and Forecasting Second edition, Springer-Verlag.
2. Feller W. (1968) Introduction to Probability Theory and its Applications, Vols. I & II, John Wiley, New York.
3. Cinlar E. (1975) Introduction to Stochastic Processes, Prentice Hall, New Jersey.
4. Basu A.K. (2003) Introduction to Stochastic Processes, Narosa, New-Delhi.
5. Bhat U.N. and Miller G. (2003) Elements of Applied Stochastic Processes. (Third edition), John Wiley, New York.
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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)** Direct Instruction, Explicit Teaching, E-learning, interactive Instruction:, Active co-operative learning, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student/ Group representative |
| **Assessment Types** | **Mode of Assessment** 1. **Continuous Internal Assessment (CIA)**
	* Internal Test -20 marks
	* Assignment – Every student needs to write an assignment on a given topic based on the available published literature – 10 marks
	* Seminar Presentation – A topic needs to be presented and discussed with the class- 10 marks
2. **Semester End examination – 60 marks**
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|  | **MAHATMA GANDHI UNIVERSITY, KOTTAYAM** |
| **MS M21E16 : MATHEMATICS FOR GENETICS AND ECOLOGY** |

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| School Name | School of Mathematics and Statistics |
| Programme | MSc Mathematics |
| Course Name  | Mathematics for Genetics and Ecology |
| Type of Course | Elective |
| Course Code | MSM21E16 |
| Course Objectives | To provide basic knowledge & skills in Statistical Genetics and Ecology for solving the emerging issues in biological modeling, ecological studies, bio-diversity assessment etc. |
| Semester  | ----- |
| Total Student Learning Time (SLT) | Learning Approach | Lecture | Tutorial | Practical | Others | Total LearningHours |
|  | Authentic learningCollaborative learning Independent learning | 75 | 20 | 0 | 25 | 120 |
| Pre-requisite | ---- |

**COURSE OUTCOMES (CO)**

|  |  |  |  |
| --- | --- | --- | --- |
| **CO No.** | **Expected Course Outcome** | **Learning Domains**  | **PSO No.** |
| 1 | Students have understood biological concepts in genetics and can explain these using probability.  | U/R  | 1,2 |
| 2 | They are able to test and detect linkage using a data. They have understood ecological issues and population growth as well as abundance.  | U/A  | 1,2 |
| 3 | They are able to compute diversity indices as well as apply game theory to explain evolutionary strategy. | U/A  | 1,2 |
| **\**Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** |

**COURSE CONTENT**

|  |  |  |  |
| --- | --- | --- | --- |
| **Module No** | **Module Content** | **CO** | **Hrs** |
| 1 | **1.1** Basic biological concepts in genetics **1.2** Mendel’s law **1.3** The law of natural selection, mutation and genetic drift **1.4** Hardy-Weinberg equilibrium, estimation of allele frequency (dominant/co-dominant cases) **1.5** Approach to equilibrium for X-linked gene. **1.6** Non-random mating and inbreeding **1.7** phenotypic assortative mating,  | 1,2,3 | 20 |
| 2 | **2.1**.Pedigree data: Elston-Stewart algorithm for calculation of likelihood **2.2**. Linkage, **2.3** Genetic mapping **2.4** Linkage equilibrium **2.5** Partitioning of Chi-square **2.6** Detection of linkage and estimation of re-combination fraction **2.6** inheritance of quantitative traits.  | 1,2,3 | 20 |
| 3. | **3.1** Introduction to ecology and evolution **3.2** population dynamics: single species-Exponential, Logistic and Gompertz models 3**.3** Leslie matrix model for age and stage Structured population 3**.4** survivorship curves-Constant, monotone and bath tub shaped hazard rates 3**.5** Two species: Lotka-Volterra equations 3**.6** isoclines  | 1,2,3 | 17 |
| 4 | **4.1**Abundance estimation: Capture–recapture **4.2** Nearest Neighbour **4.3** line transect sampling **4.4** indirect methods**. 4.5** Ecological Diversity: Species abundance curve, indices of diversity (Simpson’s index, Shannon-Wiener index) **5.6** Game theory in ecology – **4.7** Evolutionarily stable strategy, its properties**, 4.8** simple games such as Hawk-Dove game, Prisoner’s dilemma. | 1,2,3 | 18 |
| **Total Credits of the Course** | 4 |  |

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| **Text Book:**  |
| 1. Anil Gore & Sharayu Paranjpe (2001). A Course in Mathematical and Statistical Ecology, Kluwer academic Publishers.
2. Lange, K (2002). A Course in Mathematical and Statistical Methods for Genetic Analysis, Springer.
3. Falconer D.S.(1991) Introduction to Quantitative Genetics, ELBS Logman group.
 |
| **References** |
| 1. Gardner E.J. & Simmons D. P.(2007) Principles of Genetics, John Wiley & Sons Inc.
2. Lange, K (2002). Mathematical and Statistical Methods for Genetic Analysis, Springer.
3. Robert J Booker (2009) Genetics: Analysis & Principles, McGraw-Hill.
4. Robert H Tamarin, (2001) Principles of Genetics, McGraw-Hill
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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)** Direct Instruction, Explicit Teaching, E-learning, interactive Instruction:, Active co-operative learning, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student/ Group representative |
| **Assessment Types** | **Mode of Assessment** 1. **Continuous Internal Assessment (CIA)**
	* Internal Test -20 marks
	* Assignment – Every student needs to write an assignment on a given topic based on the available published literature – 10 marks
	* Seminar Presentation – A topic needs to be presented and discussed with the class- 10 marks
2. **Semester End examination – 60 marks**
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|  | **MAHATMA GANDHI UNIVERSITY, KOTTAYAM** |
| **MS M21E17 : ACTUARIAL MATHEMATICS** |

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| School Name | School of Mathematics and Statistics |
| Programme | MSc Mathematics |
| Course Name  | Actuarial Mathematics |
| Type of Course | Elective |
| Course Code | MSM21E17 |
| Course Objectives | Toenable the students to get basics in the emerging field of actuaries and insurance and to determine the annuity, and determine the same based of the residual life. |
| Semester  | ----- |
| Total Student Learning Time (SLT) | Learning Approach | Lecture | Tutorial | Practical | Others | Total LearningHours |
|  | Authentic learningCollaborative learning Independent learning | 75 | 20 | 0 | 25 | 120 |
| Pre-requisite | ---- |

**COURSE OUTCOMES (CO)**

|  |  |  |  |
| --- | --- | --- | --- |
| **CO No.** | **Expected Course Outcome** | **Learning Domains**  | **PSO No.** |
| 1 | The students will understand various aspects of insurance and actuarial statistics. | U/R  | 1,2 |
| 2 | They are capable of computing interest, discount factor , annuities, premium etc. | U/A  | 1,2 |
| **\**Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** |

**COURSE CONTENT**

|  |  |  |  |
| --- | --- | --- | --- |
| **Module No** | **Module Content** | **CO** | **Hrs** |
| 1 | **1.1** Insurance Business – Introduction, Insurance Companies as Business Organizations,**1.2** Concept of Risk; Future Lifetime Distribution and Life Tables –**1.3** Future Lifetime Random Variable, Curate Future Lifetime,**1.4** Life Tables, Assumptions for Fractional Ages, Select and Ultimate Life Tables.  | 1,2 | 20 |
| 2 | **2.1** Actuarial Present Values or Benefit in Life Insurance Products **2.2** Compound Interest and Discount Factor,**2.3** Benefit Payable at the Moment of Death, Benefit Payable at the End of Year of Death, Relation between and . | 1,2 | 20 |
| 3. | **3.1** Annuities – Annuities Certain, Continuous Life Annuities, Discrete Life Annuities, Life Annuities with monthly Payments; **3.2** Premiums - Loss at Issue Random Variable, Fully Continuous Premiums, Fully Discrete Premiums,**3.3** True monthly Payment Premiums, Gross Premiums.  | 1,2 | 17 |
| 4 | **4.1** Reserves - Fully Continuous Reserves, Fully Discrete Reserves; **4.2** Multiple Life Contracts – Joint Life Status, **4.3** Last Survivor Status. | 1,2 | 18 |
| **Total Credits of the Course** | 4 |  |

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| **Text Book:**  |
| 1. Promislow, S.D (2006) Fundamentals of Actuarial Mathematics, John Wiley.
2. Deshmukh, S.R. (2009) Actuarial Statistics – An Introduction using R, University Press (India) Pvt Ltd., Hyderabad, (Chapters 1, 4, 5, 6, 7, 8 and 9.)
 |
| **References** |
| 1. Daykin, C.D, Pentikainen,T. et al, Practical Risk Theory of Actuaries, Chapman and Hill .
2. Neill, A (1977) Life Contingencies, Heinemann , London.
3. King,G. Institute of Actuaries Text Book. Part 11, Second Edition, Charles and Edwin Layton, London.
4. Donald D.W.A.(1970) Compound Interest and Annuities, Heinemann, London.
5. Jordan, C.W.Jr.(1967) Life Contigencies, Second Edition, Chicago Society of Actuaries.
6. Spurgeen, E.T. Life Contigencies, 3rd Edition, Cambridge University Press.
7. Benjamin, B. and Pollard, J.H.(1980) Analysis of Mortality and other Actuarial Statistics, Second Edition, Heinemann, London.
8. Freeman,H.(1960) Finite Differences for Actuarial Students, Cambridge University Press.
9. Biandt-Johnson, R. C. and Johnson, N.L(1980) Survival Models and Data Analysis, John Wiley
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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)** Direct Instruction, Explicit Teaching, E-learning, interactive Instruction:, Active co-operative learning, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student/ Group representative |
| **Assessment Types** | **Mode of Assessment** 1. **Continuous Internal Assessment (CIA)**
	* Internal Test -20 marks
	* Assignment – Every student needs to write an assignment on a given topic based on the available published literature – 10 marks
	* Seminar Presentation – A topic needs to be presented and discussed with the class- 10 marks
2. **Semester End examination – 60 marks**
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|  | **MAHATMA GANDHI UNIVERSITY, KOTTAYAM** |
| **MS M21E18: NUMERICAL ANALYSIS WITH PYTHON3** |

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| --- | --- |
| School Name | School of Mathematics and Statistics |
| Programme | MSc Mathematics |
| Course Name  | Numerical Analysis with Python3 |
| Type of Course | Elective |
| Course Code | MSM21E18 |
| Course Objectives |  |
| Semester  | ----- |
| Total Student Learning Time (SLT) | Learning Approach | Lecture | Tutorial | Practical | Others | Total LearningHours |
|  | Authentic learningCollaborative learning Independent learning | 75 | 20 | 0 | 25 | 120 |
| Pre-requisite | Before going into mathematics programming part, an introduction to Python should be given. No questions should be included in the end semester examination from this unit. Internal examinations may test the knowledge of concepts from this section. **From Text 1,** Chapter 2 full – calculations and variables, Chapter 3 – creating strings, lists are more powerful than strings, tuples, Chapter 5- If statements, if-then-else statements, if and elif statements, combining conditions, the difference between strings and numbers, Chapter 6 – using for loops, while we are talking about looping, Chapter 7 – using functions, parts of a function, using modules Chapter 9 – The functions abs, float, int, len, max, min, range, sum **From Text 2** Chapter 1 - section complex numbers [Though any version of Python 3 software can be used for practical sessions, to avoid difficulty in getting and installing required modules like numpy, scipy etc, and for uniformity, the Python3 package *Anaconda 2018.x* (https://www.anaconda.com/distribution/#download-section) may be installed and used for the practical sessions. However, a brief introduction on how to use Python IDLE 3 also should be given. 1. Instead of assignments, a practical record book should be maintained by the students. Atleast 15 programmes should be included in this record book.
2. Internal assessment examinations should be conducted as practical lab examinations by the faculty handling the paper.
3. End semester examination should focus on questions including concepts from theory and programming. However, more importance should be given to theory in the end semester examinations as internal examinations will be giving more focus on programming sessions.]
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**COURSE OUTCOMES (CO)**

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| --- | --- | --- | --- |
| **CO No.** | **Expected Course Outcome** | **Learning Domains**  | **PSO No.** |
| 1 | Students will get a basic knowledge on programming using Python | U/R  | 1,2 |
| 2 | They will learn to solve mathematical/statistical problems using Python | U/A  | 1,2 |
| 3 | They will learn how to use Python for basic data analysis | U/A/An  | 1,2 |
| **\**Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** |

**COURSE CONTENT**

|  |  |  |  |
| --- | --- | --- | --- |
| **Module No** | **Module Content** | **CO** | **Hrs** |
| 1 | Defining Symbols and Symbolic Operations, Working with Expressions, Solving Equations and Plotting Using SymPy, problems on factor finder, summing a series and solving single variable inequalities Chapter 4 - From text 2 | 1,2,3 | 20 |
| 2 | Finding the limit of functions, finding the derivative of functions, higher-order derivatives and finding the maxima and minima and finding the integrals of functions are to be done. in the section programming challenges, the following problems - verify the continuity of a function at a point, area between two curves and finding the length of a curve (Chapter 7 from text 2) | 1,2,3 | 20 |
| 3. | Interpolation and Curve Fitting - Polynomial Interpolation - Lagrange's Method, Newton's Method and Limitations of Polynomial Interpolation, Roots of Equations - Method of Bisection and Newton-Raphson Method. (Chapter 3: Sections 3.1, 3.2, Chapter 4, sections 4.1, 4.3, 4.5 From Text 3) | 1,2,3 | 17 |
| 4 | Gauss Elimination Method (excluding Multiple Sets of Equations), Doolittle's Decomposition Method only from LU Decomposition Methods Numerical Integration, Newton-Cotes Formulas, Trapezoidal rule, Simpson's rule and Simpson's 3/8 rule.(Chapter 2, sections 2.2, 2.3 , Chapter 6, sections 6.1, 6.2 From Text 3. ) | 1,2,3 | 18 |
| **Total Credits of the Course** | 4 |  |

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| **Text Book:**  |
| 1. Jason R Brigs , Python for kids – a playful introduction to programming, No Starch Press
2. Amit Saha, Doing Math with Python, No Starch Press, 2015.
3. Jaan Kiusalaas, Numerical Methods in Engineering with Python3, Cambridge University Press.
 |
| **References** |
| 1. A primer on scientific programming with python, 3rd edition, Hans Petter Langtangen, Springer
2. Vernon L. Ceder, The Quick Python Book, Second Edition, Manning.
3. NumPy Reference Release 1.12.0, Written by the NumPy Community. (available for free download at https://docs.scipy.org/doc/numpy-dev/numpy-ref.pdf)
4. S. D. Conte and Carl de Boor, Elementary Numerical Analysis – An algorithmic approach, Third Edition, McGraw-Hill Book Company.
5. Sastry,S.S. Introductory Methods of Numerical Analysis, Fifth Edition, PHI.
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| **Teaching and Learning Approach** | **Classroom Procedure (Mode of transaction)** Direct Instruction, Explicit Teaching, E-learning, interactive Instruction:, Active co-operative learning, Seminar, Group Assignments, Authentic learning, Library work and Group discussion, Presentation by individual student/ Group representative |
| **Assessment Types** | **Mode of Assessment** 1. **Continuous Internal Assessment (CIA)**
	* Internal Test -20 marks
	* Assignment – Every student needs to write an assignment on a given topic based on the available published literature – 10 marks
	* Seminar Presentation – A topic needs to be presented and discussed with the class- 10 marks
2. **Semester End examination – 60 marks**
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|  | **MAHATMA GANDHI UNIVERSITY, KOTTAYAM** |
| **MS M 21 O 01: Advanced Research Methodology** |

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| School Name | School of Mathematics and Statistics |
| Programme | MSc Mathematics |
| Course Name  | **MS M 21 O 01: Advanced Research Methodology** |
| Type of Course | OPEN |
| Course Code | **MS M 21 O 01** |
| Course Objectives | To impart basic knowledge in Research Methodology, Latex Documentation, presentation etc |
| Semester  | ----- |
| Total Student Learning Time (SLT) | Learning Approach | Lecture | Tutorial | Practical | Others | Total LearningHours |
|  | Authentic learningCollaborative learning Independent learning | 75 | 20 | 0 | 25 | 120 |
| Pre-requisite | Computer basics  |

**COURSE OUTCOMES (CO)**

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| **CO No.** | **Expected Course Outcome** | **Learning Domains**  | **PSO No.** |
| 1 | Students will get a basic knowledge on programming using Python | U/R  | 1,2 |
| 2 | They will learn to solve mathematical/statistical problems using Python | U/A  | 1,2 |
| 3 | They will learn how to use Python for basic data analysis | U/A/An  | 1,2 |
| **\**Remember (R), Understand (U), Apply (A), Analyse (An), Evaluate (E), Create (C), Skill (S), Interest (I) and Appreciation (Ap)*** |

**COURSE CONTENT**

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| **Module No** | **Module Content** | **CO** | **Hrs** |
| 1 | Introduction to LaTeX, Beginning and Margin Settings, Compiling, Typing Math formulas, Alignment environment, Gather environment, Matrix, Formatting Features, Sizes, Accents in Mathematical Mode, Mathematical Symbols, Large Operators, Binary Operations, Relations, Arrows, Openings and Closings, Greek Letters and special Symbols, Array, Tables, List, Theorem, Corollary, Footnote, Equation, Standard Functions, Quotations, Comments, Convert pdf slide,  | 1,2,3 | 20 |
| 2 | Introduction to Research, Defining the Research Problem, Research Formulation, Research Design: – Basic Principles- Need of research design –– Features of good design – Important concepts relating to research design , Development of Models. Developing a research plan - Exploration, Description, Diagnosis, Experimentation, Experimental and sample designs, Data Collection and analysis, Sampling Techniques, Research Methods and Tools, Web resources, and Journals. | 1,2,3 | 20 |
| 3. | Reporting and thesis writing – Structure and components of scientific reports, Types of report , Layout, structure and Language of typical reports – Illustrations and tables , Bibliography, referencing and footnotes - Oral presentation, Planning , Preparation, Practice, Making presentations , Use of visual aids - Importance of effective communication , Journal paper writing, Project report, Technical reports , thesis writing.­­­­­­­­­­­­­­­ | 1,2,3 | 17 |
| 4 | **R for Data Analytics:** Introduction to R, Descriptive statistics, Data Visualization techniques-, Probability distributions, Correlation and Regression, Tests of hypotheses, ANOVA, Applications in Data analysis.**Python for Data Science:** Introduction, NumPy, Pandas, Basic statistics, Generation of random variables, Simulation studies, Hypothesis testing, estimation of parameters, ANOVA and MANOVA tests.**Practical**: Preparing a document of at least 10 pages using LaTeX , Journal paper preparation and presentation, Case studies presentation using R and Python with real data sets. Practical to be done in the computer lab and practical record to be submitted. | 1,2,3 | 18 |
| **Total Credits of the Course** | 4 |  |

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| **Text Book:**  |
| 1. Dilip Datta, LaTeX in 24 Hours: A Practical Guide for Scientific Writing. Springer, 2017 .
2. George Gratzar, Practical LaTex. Springer, 2014.
3. Hadley W, Garret E (2016) , R for Data Science, O’Reilly.
4. Antony S, (2018), Data Analysis with R, 2nd Edition, Packt publishing
5. Gaje Valder Plos, 2016, Python Data Science Handbook, O’Reilly Media.
6. Sagii L, 2018, Python Data analytics: with Pandas, NumPy, Matplotlib, APress

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| **References** |
| 1. Leslie Lamport, LaTeX : A Document Preparation System.
2. Stefan Kottwitz, LaTeX :Beginner’s Guide: Create high-quality and professional –looking texts,articles and books for business and science using LaTeX, 2011.
3. Kothari C R, Research Methodology: Methods and Techniques, 2004.
4. Gay L R 1981, 2nd edition, Educational Research, Columbus OSIO.
5. Long J S, 1988, Common Problems Proper Solutions on Avoiding errors in Quantitative Rsearch, Begerly, Sage Publications, California.
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**Mahatma Gandhi University, Kottayam**

**School of Mathematics & Statistics**

**M.Sc. Mathematics Semester 1: End Semester Examination May 2022**

**MS M1 21 C01 - LINEAR ALGEBRA**

**Time : 3 hours Max. Marks: 60**

**PART A (Answer all questions. Each question carries 1 mark.)**

1. Which of the following sets of vectors are subspaces of

a). All such that b). All such that

c). All such that d). All such that

1. Which of the following is a linear transformation

a). b).

c). d).

1. Let be the ring of polynomials over the field of real numbers and , then

a). b). c). d). 2

1. Let be an invertible linear operator on a finite dimensional space , then which of the following is true?

a). b).

 c). d).

1. Let be a -dimensional vector space over the field . What is the minimal polynomial for the identity operator on ?

a). b). c). d).

**PART B (Answer any 5 questions. Each question carries 2 marks.)**

1. Let be a linear transformation on a vector space . Then show that .
2. Obtain the dimension of the vector space of all matrices over the field.
3. Let be a linear operator defined on defined by . What is the matrix of in ordered basis for where and ?
4. Prove that is one-one if and only if is non-singular.
5. Let be linear where and are vector spaces over . Show that the r is the annihilator of the null space of .
6. Find the subspace annihilated by the following functionals on

a). b).

1. Let be the linear operator on , the matrix of which in the standard ordered basis is Find all subspaces of that invariant under .
2. Let be a linear operator on . Let be any linear operator on which commutes with . Let be the range of and be the null space of , Then prove that and are invariant under T.

**PART C (Answer any 5 questions. Each question carries 5 marks.)**

1. Let be the vector space of all matrices over the field .Let be the set of matrices of the form and let be the set of matrices of the form

(i) Prove that and are subspaces of

(ii) Find the dimension of

1. Let be a finite dimensional vector space over the field and let be an ordered basis for . Let be a vector space over the same field and let be any vectors in .Then prove that there is precisely one linear transformation from into such that
2. Let be finite dimensional vector space over the field . Show that is isomorphic to .
3. Define annihilator of a subspace of . Show that if is a subspace of a finite dimensional vector space , then .
4. Show that the determinant of the matrix is
5. Let be linear functionals on a vector space with respective null spaces . Then prove that is a linear combination of if and only if contains the intersection .
6. Define minimal polynomial for a linear operator . Show that the characteristic polynomial and minimal polynomial for a linear operator have the same roots except for multiplicities.
7. In let .

a) If is a linear functional on such that and if find .

b) Describe explicitly a linear functional on such that and

**PART D (Answer any 2 questions. Each question carries 10 marks.)**

1. a). Define a non-singular linear transformation and prove that ``If is a linear transformation from into . Then is non-singular if and only if carries each linearly independent subset of onto a linearly independent subset of ".

b). Let be the subspace of spanned by and

 (i) Show that and form a basis for .

 (ii) Show that the vectors and are in and form another

 basis for .

1. a). State and prove rank-nullity theorem.

 b). Let be linear where and are vector spaces over . Show that the r.

1. a). Prove that ``A linear combination of -linear functions is -linear".

 b). Use Carmer's rule to solve the system of equations

1. Let be a finite dimensional vector space over the field and let be a linear operator on . Prove that is diagonalizable if and only if the minimal polynomial for has the form where are distinct elements of .

**Mahatma Gandhi University, Kottayam**

**School of Mathematics & Statistics**

**M.Sc. Mathematics Semester 1: End Semester Examination May 2022**

**MS M1 21 C03 - TOPOLOGY**

**Time : 3 hours Max. Marks: 60**

**PART A (Answer all questions. Each question carries 1 mark.)**

1. Which of the following is a basis for a topology on ℝ

a). b). c).

d).

1. Which of the following is an open set in with standard topology

a). (0,1) b). (0,1] c). {1} d). [1,2)

1. Which of the following is a compact topological space

a). with usual topology b). with finite complement topology

c). with discrete topology d). with lower limit topology

1. Let be a topological space. Then each component of is

a). Closed in b). Open in c). Dense in d). both open and closed in

1. Let be an open set in a topological space . Then

a). b). c). d). none of these

**PART B (Answer any 5 questions. Each question carries 2 marks.)**

1. Determine all the possible topologies on .
2. Let be a basis. Assume that and that . Then show that there exists such that .
3. Let be a topological space, and let have the subspace topology. If is open in , and is open in , show that is open in
4. Show that if and are Hausdorff spaces, so is their product .
5. Every metric space is Hausdorff.
6. Let be a metric space, and assume and . Provide an example showing that need not imply that .
7. Let be continuous and let be compact in . Then is compact in .
8. If is connected and is continuous, then is connected in .

**PART C (Answer any 5 questions. Each question carries 5 marks.)**

1. Determine whether the set form a basis for a topology on ?
2. Prove that open balls are open sets in the standard topology on .
3. Let and be subsets of topological spaces and . Show that if and , then .
4. A function is continuous in the open set definition of continuity if and only for every and every open set containing , there exists a neighborhood of such that .
5. Let and be metrics on a set , and let and , respectively, be the topologies that they induce. Then is finer than if and only if for each and , there exists a such that .
6. Show that the taxicab metric on satisfies the properties of a metric.
7. Prove that an infinite set with the finite complement topology is a connected topological space.
8. Provide an example of closed sets, and , in a metric space such that and are disjoint and .

**PART D (Answer any 2 questions. Each question carries 10 marks.)**

1. Define closed set in a topological space . Let be a topological space. Show that the following statements about 𝓒, the collection of closed sets in hold:

(i) and are closed.

(ii) The intersection of any collection of closed sets is a closed set.

(iii) The union of finitely many closed sets is a closed set.

1. a). Let and be topological spaces and be a basis for the topology on . Then is continuous if and only if is open in for every .

b). Let and be topological spaces and be their product. Let is open in and is open in . Prove that the set is a basis for the product topology.

1. a). What you mean by a regular topological space. Prove that with the lower limit topology is a regular topological space.

b). Show that if is regular and is homeomorphic to , then is regular.

1. a). Let have the standard topology and the standard metric . A set is compact in if and only if it is closed and bounded.

 b). Let be a Cauchy sequence in with the standard metric . Then converges

 to a limit in .