# ORDINANCE

FOR

# MASTER OF SCIENCE – MATHEMATICS

GNA UNIVERSITY

*Inspiring Innovation.....*

(THIS ORDINANCE HAS BEEN APPROVED IN THE MEETING OF BOARD OF STUDIES HELD ON DATED 31st May, 2022)

**APPLICABLE W.E.F. ACADEMIC SESSION 2022-2023**

SRI HARGOBINDGARH, PHAGWARA – HOSHIARPUR ROAD,
PHAGWARA 144401, PUNJAB

SRI HARGOBINDGARH, PHAGWARA – HOSHIARPUR ROAD,PHAGWARA 144401, PUNJAB

# ORDINANCE FOR M.SC. MATHEMATICS

**SHORT TITLE AND COMMENCEMENT**

I. This Ordinance shall be called the Ordinance for the M.Sc. Mathematics Program of GNA University, Phagwara.

II. This Ordinance shall come into force with effect from academic session 2020 - 21

**1. Name of Program: Master of Science in Mathematics**

**2. Name of Faculty: Faculty of Natural Sciences.**

**3. Vision of the department:** To Produce highly qualified Mathematicians and professionals in the field of Mathematical Science accepting globally for catering the need of the society.

**4. Mission of the department:**

**M1:** To prepare students with practical &technical aspects of chemistry, which they are ready to take the new real-world challenges.

**M2:** Establish an industry-academia relationship to enhance the technical skills of students to work prominently in industrial environments.

**M3:** Provide exposure to students of state-of-the-art tools and technology in the field of chemistry

**M4:** Each Faculty member motivates students to become problem-solving individuals, researcher, a good academician in the field of chemistry.

**5. Program Educational Outcomes (PEO):**

**PEO1:** To excel in academic development skills coveted in the Mathematical industry.

**PEO2:** To evolve student as globally competent professionals possessing leadership skills for developing innovative solutions in multidisciplinary domains.

**PEO3:** To involve student in lifelong learning to adapt the technological advancements in the emerging areas of applications of mathematics.

**PEO4:** To provide student with an academic environment that fosters excellence, transparency, leadership and promote awareness of life-long learning.

**PEO5:** To Work as teams to solve problem solving of different field using different mathematical concepts.

**6. Program Outcomes (PO):**

**PSO1:** Professional Skills: Attain the ability to handle various mathematical problems and applying different methods to solve them mathematically.

**PSO2:** Successful Career and Entrepreneurship: Explore technical knowledge in diverse areas of mathematics and experience an environment conducive in cultivating skills for successful career, entrepreneurship, and higher studies.

**PSO3:** Problem Solving: Ability to use knowledge gained for solving complex reactions using various methods & technology.

**7. Program Specific Outcomes:**

**PO1: Basic knowledge:** An ability to apply knowledge of basic mathematics in different field.

**PO2: Discipline knowledge:** An ability to apply discipline specific knowledge to solve core and/or applied and pure mathematics.

**PO3: Modern Tool Usage:** Use current techniques, skills, and tools necessary to carry out various analytical methods for problem solving.

**PO4: Ethics:** Recognize the social and ethical responsibilities of a professional working in the discipline.

**PO5: Computing Skills:** Analyze a problem and identify and define the computingrequirements appropriate to its solution.

**PO6: Profession and society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional practice.

**PO7: Environment and sustainability:** Understand the impact of the professional solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

**PO8: Individual and teamwork:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

**PO9: Social Contribution**: Follow professional mathematician by applying contextual ] knowledge to assess societal and legal issues.



**PO10: Communication:** Communicate effectively on complex activities and with the society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

**PO11: Project management and finance:** Demonstrate knowledge and understanding of the management principles and apply these to one's own work, as a member and leader in a team.

**PO12: Lifelong Learning:** Work as teams to work on different projects using programming and different mathematical problem-solving techniques.

**8.** General Regulations for Faculty of Natural Sciences:

**8.1** The University may introduce programs under Faculty of Natural Sciences which are specified under the UGC Act 1956. The Governing Body may approve the introduction, suspending or phasing out a program on the recommendation of the Academic Council either on its own or on the initiative of faculty.

**8.2** The admissions to a Faculty of Natural Sciences programs shall be generally governed by the rules of the UGC or any other competent authority of the MHRD or as approved by Governing Body of University and shall be as notified in the admission notification of the respective academic year.

**8.3** The minimum entry qualification for admission to the students of Faculty of Natural Sciences shall be such as may be laid down in the regulations or specified by the Governing Body like Minimum qualification for admission to the first year program of Faculty of Natural Sciences shall be the Senior Secondary School Certificate (10+2) examination. While deciding the admission procedure, the University may lay down compulsory subjects in qualifying examination for admission for various programs in the admission policy.

**8.4** A student shall be required to earn a minimum number of credits through various academic components of a curriculum, as provided for in the regulations.

**8.5** A student shall be required to complete all the requirements for the award of the degree within such period as may be specified in the regulations.

**8.6** A student may be granted such scholarship as may be specified in accordance with the directions of the Governing Body from time to time or regulations laid down for the same.

**8.7** A student admitted to the programs shall be governed by the rules, regulations and procedures framed and implemented by the University from time to time.

**8.8** The students shall abide by the regulations mentioned in student handbook issued by the University. These standing regulations shall deal with the discipline of the students in the Hostels, Faculty, and University premises or outside. The standing orders may also deal with such other matters as are considered necessary for the general conduct of the students' co-curricular and extra-curricular activities.

**8.9** In exceptional circumstances the chairman of Academic Council may, on behalf of the Council, approve amendments, modifications, Insertions or deletions of an Ordinance(s) which in his/her opinion is necessary or expedient for the smooth running of the program provided all such changes are reported approved to the Council in its next meeting.

**9. General Regulations for the Master of Science in Mathematics:**

**9.1 Short Title and Commencement:** These regulations shall be called regulations for the PG programs in Faculty of Natural Sciences of the University and shall come into force on such a date as the Academic Council may approve.

**9.2 Duration:** The duration of the PG programs leading to degrees of M.Sc. Mathematics shall be minimum two years and each year will comprise of two semesters. However, the duration may be extended up-to five years from the registered batch. The maximum duration of the programs excludes the period of withdrawal, due to medical reasons. However, it shall include the period of rustication or any other reason of discipline /academics e.g. detention, willful absence by the student, not getting promotion to the next class due to poor academic performance etc. Under detention, the student shall attend the University for an additional semester or more time, as equated to period of absence/suspension.

**9.3 Starting or Phasing out of Program:** A program may be phased out on recommendations of the Academic Council and approval of the Governing Body, on account of continuous low registration in the program or any other justifiable reason like becoming obsolete etc. Similarly, the Academic Council may approve starting of a new program or modifying the existing one on the recommendations of the Academic Council.

**9.4 Admissions:** The centralized admission cell shall make selection for admission to the program. Admission to this program shall be made as per procedure to be approved by the Academic Council, and further by Board of Management and Governing Body and may be reviewed periodically as required. Eligibility criteria for the program, meriting and selection policy, fee structure, refund policy, total number of seats etc. shall be defined in the admission policy.

**9.5 Eligibility for Admission:** B.Sc. NM / B.Sc. (Hons.) chemistry with 50% marks in aggregate (45 % for SC/ST/OBC).

**9.6 Semester System:** The Bachelor of Science - Physics academic programs in the University shall be based on Semester System, namely, Even (Jan to June) and Odd (July to Dec) Semesters, in an academic year. The courses whether offered in regular semester shall be evaluated as per the policy and procedure laid down.

**9.7 Semester Duration:** Total duration of the Program shall be of two years and each year will comprise of two semesters. In addition, each semester shall normally have teaching for the 90 working days.

**10. Curriculum:** The three years curriculum has been divided into six semesters and shall include lectures, tutorials, practical, and projects along with the industrial visits and educational tours etc. The curriculum will also include other curricular, co-curricular and extra-curricular activities as may be prescribed by the University from time to time.

**11. Choice Based Credit System:**

The University has adapted Choice Based Credit System (CBCS) which provides an opportunity for the students to choose courses from the prescribed courses comprising core, elective/minor or skill based courses. The choice based credit system provides a "flexible" approach in which the students can take courses of their choice, learn at their own pace, undergo additional courses and acquire more than the required credits, and adopt an interdisciplinary approach to learning. Following are the types of courses and structure for the program:

**11.1 Core Course:** A course, which should compulsorily be studied by a candidate as a core requirement is termed as a core course.

**11.2 Elective Course:** Generally a course which can be chosen from a pool of courses and which may be very specific or specialized or advanced or supportive to the discipline/subject of study or which provides an extended scope or which enables an exposure to some other discipline/subject/domain or nurtures the candidate's proficiency/skill is called an Elective Course.

**i. Discipline Specific Elective (DSE) Course:** Elective courses may be offered by the main discipline/subject of study is referred to as Discipline Specific Elective. The University/Institute may also offer discipline related Elective courses of interdisciplinary nature (to be offered by main discipline/subject of study).

**ii. Dissertation/Project:** An elective course designed to acquire special/advanced knowledge, such as supplement study/support study to a project work, and a candidate studies such a course on his own with an advisory support by a teacher/faculty member is called dissertation/project.

**12. Medium of Instructions:**

**12.1** The medium of instructions and examination will be English.

**12.2** Question Papers of all examinations will be set and answered in English.

**12.3** Practical work/Project Work / Project Report / Dissertation / Field Work Report / Training Report etc., if any, should be presented in English.

**13. Mode:** The program is offered on 'Full Time' mode of study only.

**14. Attendance Requirement to be Eligible to Appear in End Semester Examination:**

**14.1** Every student is required to attend at least 75% of the lectures delivered squaring tutorials, practical and other prescribed curricular and co-curricular activities.

**14.2** Dean of Faculty may give a further relaxation of attendance up to 10% to a student provided that he/she has been absent with prior permission of the Dean of the Faculty for the reasons acceptable to him/her.

**14.3** Further, relaxation up to 5% may be given by the Vice Chancellor to make a student eligible under special circumstances only.

**14.4** No student will be allowed to appear in the end semester examination if he/she does not satisfy the attendance requirements. Further, the attendance shall be counted from the date of admission in the University or commencement of academic session whichever is later.

**14.5** Attendance of N.C.C/N.S.S. Camps or Inter-Collegiate or Inter-University or Inter-State or International matches or debates or Educational Excursion or such other Inter-University activities as approved by the authorities involving journeys outside the city in which the college is situated will not be counted as an absence. However, such absence shall not exceed four weeks per semester of the total period of instructions. Such type of facility should not be availed twice during the study.



**15. Credit:** Each course, except a few special audit courses, has a certain number of credits assigned to it depending upon its lecture, tutorial and/or laboratory contact hours in a week.

A letter grade, corresponding to a specified number of grade points, is awarded in each course for which a student is registered. On obtaining a passing grade, the student accumulates the course credits as earned credits. A student's performance is measured by the number of credits that he/she has earned and by the weighted grade point average. A minimum number of credits should be acquired to qualify for the programs.

**Earned Credits (EC):** The credits assigned to a course in which a student has obtained 'D' (a minimum passing grade) or a higher grade will be counted as credits earned by him/her. Any course in which a student has obtained F, or W or "I" grade will not be counted towards his/her earned credits.

A unit by which the course is measured. It determines the number of hours of instruction required per week.

| Contact Hours per Week | Credit Assigned |
|---|---|
| 1 Hr. Lecture (L) per week | 1 credit |
| 1 Hr. Tutorial (T) per week | 1 credit |
| 2 Hours Practical (Lab) per week | 1 credit |

**16. Program Structure: As per GNA University**

**Details of Courses under M.Sc. Mathematics**

| Course | Credits |
|---|---|
| **I. Core Course** (16 papers) | 16 X 4= 64 |
| Core Course Tutorial | 16 X 1= 16 |
| **II.** Elective Course (4 Papers) | 4 X 4= 16 |
| Elective Course Tutorial | 4 X 1= 4 |
| **Total** | 100 |

## Course Structure M.Sc. Mathematics

## COURSE SCHEME

| Sr. No. | Core Course (CC) 16 | Electives (4) |
|---|---|---|
| I | CC - 1 | |
| | CC - 2 | |
| | CC - 3 | |
| | CC - 4 | |
| | CC - 5 | |
| II | CC - 6 | |
| | CC - 7 | |
| | CC - 8 | |
| | CC - 9 | |
| | CC - 10 | |
| III | CC - 11 | E – 1 |
| | CC - 12 | E – 2 |
| | CC - 13 | |
| IV | CC - 14 | E – 3 |
| | CC - 15 | E – 4 |
| | CC - 16 | |

## M. Sc. Mathematics Semester – I (First Year )

| Sr. No | Category | Course Code | Course Title | Teaching Scheme | | | credits | Hours | Examination Scheme | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | L | T | P | | | Internal | External | |
| 1 | Core -1 | MMT1101 | Real Analysis-I | 4 | 1 | 0 | 5 | 5 | 40 | 60 | 100 |
| 2 | Core -2 | MMT1102 | Algebra-I | 4 | 1 | 0 | 5 | 5 | 40 | 60 | 100 |
| 3 | Core -3 | MMT1103 | Integral Transforms & Integral Equations | 4 | 1 | 0 | 5 | 5 | 40 | 60 | 100 |
| 4 | Core -4 | MMT1104 | Complex Analysis | 4 | 1 | 0 | 5 | 5 | 40 | 60 | 100 |
| 5 | Core -5 | MMT1105 | Ordinary Differential Equations & Special Functions | 4 | 1 | 0 | 5 | 5 | 40 | 60 | 100 |



## M. Sc. Mathematics Semester – II (First Year )

| Sr. No | Category | Course Code | Course Title | Teaching Scheme | | | credits | Hours | Examination Scheme | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | L | T | P | | | Internal | External | |
| 1 | Core – 6 | MMT2101 | Number Theory | 4 | 1 | 0 | 5 | 5 | 40 | 60 | 100 |
| 2 | Core – 7 | MMT2102 | Classical Mechanics | 4 | 1 | 0 | 5 | 5 | 40 | 60 | 100 |
| 3 | Core – 8 | MMT2103 | Real Analysis-II | 4 | 1 | 0 | 5 | 5 | 40 | 60 | 100 |
| 4 | Core – 9 | MMT2104 | Algebra-II | 4 | 1 | 0 | 5 | 5 | 40 | 60 | 100 |
| 5 | Core – 10 | MMT2105 | Partial Differential Equations | 4 | 1 | 0 | 5 | 5 | 40 | 60 | 100 |

## M. Sc. Mathematics Semester – III (Second Year )

| Sr. No | Category | Course Code | Course Title | Teaching Scheme | | | credits | Hours | Examination Scheme | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | L | T | P | | | Internal | External | |
| 1 | Core – 11 | MMT3101 | Functional Analysis-I | 4 | 1 | 0 | 5 | 5 | 40 | 60 | 100 |
| 2 | Core – 12 | MMT3102 | Differential Geometry | 4 | 1 | 0 | 5 | 5 | 40 | 60 | 100 |
| 3 | Core – 13 | MMT3103 | Probability Theory | 4 | 1 | 0 | 5 | 5 | 40 | 60 | 100 |
| 4 | ELECTIVE – 1 | MMT**** | ELECTIVE – 1 | 4 | 1 | 0 | 5 | 5 | 40 | 60 | 100 |
| 5 | ELECTIVE – 2 | MMT**** | ELECTIVE – 2 | 4 | 1 | 0 | 5 | 5 | 40 | 60 | 100 |

## M. Sc. Mathematics Semester – IV (Second Year )

| Sr. No | Category | Course Code | Course Title | Teaching Scheme | | | credits | Hours | Examination Scheme | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | L | T | P | | | Internal | External | |
| 1 | Core – 14 | MMT4101 | Topology | 4 | 1 | 0 | 5 | 5 | 40 | 60 | 100 |
| 2 | Core – 15 | MMT4102 | Functional Analysis-II | 4 | 1 | 0 | 5 | 5 | 40 | 60 | 100 |
| 3 | Core – 16 | MMT4103 | Measure Theory | 4 | 1 | 0 | 5 | 5 | 40 | 60 | 100 |
| 4 | ELECTIVE – 3 | MMT**** | ELECTIVE – 3 | 4 | 1 | 0 | 5 | 5 | 40 | 60 | 100 |
| 5 | ELECTIVE – 4 | MMT**** | ELECTIVE – 4 | 4 | 1 | 0 | 5 | 5 | 40 | 60 | 100 |

**Elective Subjects Bucket (05 Credits each)**

| Sr. No | Course Code | Course Name | L | T | P | Credits |
|---|---|---|---|---|---|---|
| 1. | MMT3104 | Operations Research-I | 4 | 1 | 0 | 5 |
| 2. | MMT3105 | Discrete Mathematics-I | 4 | 1 | 0 | 5 |
| 3. | MMT3106 | Fluid Dynamics | 4 | 1 | 0 | 5 |
| 4. | MMT3107 | Advanced Numerical Analysis | 4 | 1 | 0 | 5 |
| 5. | MMT3108 | Stochastic Process | 4 | 1 | 0 | 5 |
| 6. | MMT3109 | Commutative Algebra | 4 | 1 | 0 | 5 |
| 7. | MMT3110 | Theory of Wavelets | 4 | 1 | 0 | 5 |
| 8. | MMT3111 | Fourier Analysis | 4 | 1 | 0 | 5 |
| 9. | MMT3112 | Topics in Linear Algebra | 4 | 1 | 0 | 5 |
| 10. | MMT3113 | Topological Vector Spaces | 4 | 1 | 0 | 5 |
| 11. | MMT3114 | Computer Programming with C | 4 | 1 | 0 | 5 |
| 12. | MMT3115 | Operations Research-II | 4 | 1 | 0 | 5 |
| 13. | MMT3116 | Discrete Mathematics-II | 4 | 1 | 0 | 5 |
| 14. | MMT3117 | Banach Algebra and Operator Theory | 4 | 1 | 0 | 5 |
| 15. | MMT3118 | Financial Derivatives | 4 | 1 | 0 | 5 |
| 16. | MMT3119 | Theories of Integration | 4 | 1 | 0 | 5 |
| 17. | MMT3120 | Algebraic Topology | 4 | 1 | 0 | 5 |
| 18. | MMT3121 | Theory of Sample Survey | 4 | 1 | 0 | 5 |
| 19. | MMT3122 | Special Functions | 4 | 1 | 0 | 5 |
| 20. | MMT3123 | Representation Theory of Finite Groups | 4 | 1 | 0 | 5 |
| 21. | MMT3124 | Analytic Number Theory | 4 | 1 | 0 | 5 |

*** Note: The electives will be offered to the students depending upon the availability of the teachers. The decision of the Head of the Department in this respect will be final.**

**17. Examination/ Evaluation System:**

**17.1 Internal Assessment,** which includes attendance, mid semester examination and other components (Project 1, Project 2, Mid Term Exam, Attendance, Class Test) carrying a weightage of 40%. This is applicable for all theory courses.

**17.2 Practical Courses:** The examination/evaluation criteria of the practical courses shall be decided by the respective faculty member and wherever required on the availability of the external experts/visiting faculty. Faculty may set/design the practical exercises out of any marks but the overall weightage shall be in pre-defined percentage, which the concerned faculty/course coordinator shall announce in the first class of the semester and upload on the GU-Academia. Methodology for evaluation of Lab component may include day to day work, lab records, quantity/quality of work and Viva/Seminar/Practical as may be decided.

**17.3 External Assessment** i.e. End Semester Examination, carrying a weightage of 60%.

a) End Semester Examination: These examinations shall be conducted by Controller of Examination. The examination dates and schedule shall be released by the University.

b) Similar division of marks may be created for special courses like Major Projects, seminars, term papers, internship etc. by respective faculty but same shall also be predefined.

c) Every student has to score at least 25% marks each in Continuous Assessment and End Semester examination. The minimum pass percentage is 40% in aggregate. In case a student scores more than 25% each in Continuous Assessment and End Semester Examination, but overall percentage in the concerned subject remains less than 40%, then student has to repeat End Semester Examination in that subject.

**17.4 Failing to meet Attendance Requirement:**

a) A student is required to attend all the classes.

b) If the attendance profile of a student is unsatisfactory, he/she will be debarred. Any student, who has been debarred due to attendance shortage, shall not be allowed to take the supplementary Examination. The student shall have to register for the course in the regular semester when offered.

**17.5 Makeup Examinations for Mid Semester Examination:** A student may apply for a makeup examination where he/she is not able to attend the examination schedule due to reasons of personal medical condition or compassionate reason like death of a very close relative. No other contingencies are acceptable. Except in case of medical emergency, a student needs to seek advance approval from appropriate authority before missing the Examination.

**Theory Courses:**

- A student missing Mid Term Examination only shall be required to take a make-up Examination.
- The students must put-up the request for make-up Examination along with the medical documents to prove the genuineness of the case (for having missed the Examination) within 5 days of last date of Examination.
- The genuineness shall be reviewed and approved by the Vice Chancellor, whose decision

shall be final.

- In case a student misses the make-up Examination also, then no further chance will be provided.
- The duration of Examination shall be as decided by the Faculty member.
- Genuine approved cases shall be notified by the Controller of Examination based on the requests received and only such students shall be allowed to take make-up Examination in the subjects where approval has been granted.
- The date sheet need not be taken out as the makeup examination shall be conducted under arrangement concerned faculty, who after evaluation and sharing the evaluated answer sheet with student shall submit marks to the Controller of Examination.

**17.6 Makeup of End Semester Examination:** It is mandatory to appear the end semester major examination to obtain any grade for a course. A student who misses the end semester major examination shall follow a similar procedure as outlined above, to obtain approval of the Vice Chancellor to prove genuineness of the case. The student whose case is approved as genuine shall be awarded "I" Grade in the semester results in the given subject. The student shall be allowed to appear in the supplementary examination of the said subject. However, the grades shall be worked out by computing the marks obtained by students in Mid Term Exams, TA, Lab and supplementary examination (equated to the weightage of end semester examination). The total marks shall be compared with the marks of the class as in the regular semester for award of grade.

**17.7 Makeup of End Semester Viva of Projects:** It is mandatory to appear in the final Viva examination to obtain any grade for a project course. In case of student missing the same for genuine reasons; similar method as given for written examination of theory courses shall be followed.

**17.8 Procedure to be adopted by students in case of missing any of the specified Examination(s):** Following procedure shall be adopted for establishing genuineness of the case.

a. Action by the student (Medical Cases)

I. They should report absence from the Examination(s) by fastest possible means to the Controller of Examination. It could be email or written communication by speed post or sent by hand through any means. In case of Hosteller's, if a student falls sick while residing in the hostel, he/she should seek advice of the available qualified doctor.

II. The said report should preferably be sent prior to the Examination, but not later than 5 days after the last date of the said Examination.

III. The student should on rejoining:

a. Report to the Controller of Examination with complete medical documents to include referral/Prescription slip of the doctor specifically indicating the disease and medicine prescribed, investigation/Lab reports and discharge slip in case of admission should be provided.

b. Submit the Documents to the Controller of Examination, not later than 5 days after the last date of Examination.

IV. In case delay beyond 5 days is anticipated the student should arrange for the medical documents to be sent to the University Medical Officer by hand through a friend / relative etc. and get the said genuineness deposit with the Controller of Examination.

V. No request later than 5 days after the last date of Examination shall be accepted for reasons of ignorance or any other reasons.

**b. Action by students (any other reason)**

In case the student must miss Examination due to genuine reason other than medical, prior written sanction of Vice Chancellor and in his absence Dean is mandatory. No post facto requests shall be accepted in any case. The approval should be deposited with the Controller of Examination before the examination.

**18. Supplementary Examination:**

**18.1** The supplementary examinations shall be held for each commiserating semester in December for Odd semester and May/June for Even semester respectively. For the final semester students, there is privilege to appear in the supplementary exams of all previous semester.

**18.2 Eligibility:** Student with 'F' grade is eligible to appear in the Supplementary Examination.

**18.3 Re-appear:** Student with backlog of one semester will be carried forward to next semester. Re-appear examinations will be conducted twice in a year after ESE of every semester.

**18.4 Supplementary for Projects:** There shall be no supplementary examinations for the projects, except makeup examination for missing the final viva as per rules outlined above.

**19. Grading System:** University follows eight letter grading system (A+, A, B+, B, C+, C, D, and F) that have grade points with values distributed on a 10 point scale for evaluating the performance of student. The letter grades and the corresponding grade points on the 10-point scale are as given in the table below. If number of passing students in any subject is less than or equal to 30 then Absolute Grading System will be followed otherwise Relative Grading System will be followed for evaluation.

| Academic Performance | Range of Marks | Grades | Grades Points | Remarks |
|---|---|---|---|---|
| Outstanding | ≥90 | A+ | 10 | |
| Excellent | ≥80 & <90 | A | 9 | |
| Very Good | ≥70 & <80 | B+ | 8 | |
| Good | ≥60 & <70 | B | 7 | |
| Fair | ≥50 & <60 | C+ | 6 | |
| Average | ≥40 & <50 | C | 5 | |
| Minimally Acceptable | 40 | D | 4 | |
| Fail | <40 | F | 0 | |
| Incomplete | | I | - | |
| Withdrawal | | W | - | |
| Grade Awaited | | GA | - | |
| **Minor Project** | | **S/US** | | **S-Satisfactory US-Unsatisfactory** |

**19.1 Description of Grades:**

**A. D Grade:** The D grade stands for marginal performance, i.e. it is the minimum passing grade in any course. D grade shall not be awarded below 30% marks, though each teacher may set higher marks for the same.

**B. F Grade:** The 'F' grade denotes a very poor performance, i.e. failing a course. A student has to repeat all courses in which she/he obtains 'F' grade until a passing grade is obtained. In the case of 'F', no Grade points are awarded. However, the credits of such courses shall be used as the denominator for calculation of GPA or CGPA.

**C. W Grade:** The 'W' grade is awarded to a student if he/she is allowed to withdraw for an entire Semester from the University on medical grounds for a period exceeding five weeks.

**D. I" Grade:** The 'I' grade is awarded when the student is allowed additional opportunity like makeup Examination etc. based on which the grade is to be decided along with other components of the evaluation during the semester 24 An incomplete grade of 'I' may be given when an unforeseen emergency prevents a student from completing the work in a course. The 'I' must be converted to a performance grade (A to F) within 90 days after the first day of classes in the subsequent regular semester.

**E. X Grade:** It is equivalent to Fail grade but awarded due to a student falling below the laid down attendance requirement. Students having X grade shall be required to re-register for the course, when offered next.

**19.2 Cumulative Grade Point Average (CGPA),** it is a measure of the overall cumulative performance of a student for all semesters. The CGPA is the ratio of total credit points secured by a student in various course in all semesters and the sum of the total credits of all courses in all the semesters. It is expressed up to two decimals places.

NB: The CGPA can be converted to percentage by using the given formula:

CGPA x 10 = %

e.g. 7.8 x 10 = 78%

**19.3** Based on the grades earned, a grade certificate shall be issued to all the registered students after every semester. The grade certificate will display the course details (Course title, number of credits, grade secured) along with SGPA of that semester and CGPA earned till that semester.

**20. General Rules: Examinations:**

**a)** Showing the Answer Scripts: The answer scripts of all written Examinations i.e. Mid Term or end semester examination or any other written work conducted by a teacher shall be shown to the students. Students desirous of seeing the marked answer scripts of End Semester Examination has to ensure their presence before results are declared, as per dates notified by the Controller of Examination.

**b)** Marks/Answer Sheets of all other tests shall also be shared with the students and thus, there shall be no scrutiny of grades. However, before the grades are forwarded to Registrar/Controller of Examination, they should be displayed on GU-Academia and time are given to students, to discuss the same with respective faculty.

**c)** No appeal shall be accepted for scrutiny of grades.

**d)** Examination Fee for Supplementary. A fee of Rs.1000/- per course or as decided by the Management from time to time will be charged from the students.

**21. Improvement of overall Score:** A candidate having CGPA < 5.5 and wishes to improve his/her overall score may do so within two academic years immediately after passing the degree program by reappearing into maximum four course(s)/subject(s). The improvement would be considered if and only if the CGPA becomes > 5.5.

**22. Program qualifying criteria:** For qualifying the Program every student is required to earn prescribed credits (i.e. 100) If any student fails to earn prescribed credits for the program then he/she will get a chance to complete his/her Program in two more years than the actual duration of degree.

**23. Revision of Regulations, Curriculum and Syllabi:** The University may revise, amend, change, or update the Regulations, Curriculum, Syllabus and Scheme of examinations through the Board of Studies and the Academic Council as and when required.

**24. Conditions for Award of a Degree:** Should complete the requirements of the Degree in maximum duration specified for the program. Semester withdrawals due to medical reasons are not counted in six years. However, forced withdrawal of students e.g. rustication or expulsion or nonattendance by student due to any other reasons, shall count in the maximum period of six years and minimum period of four years.



GNA UNIVERSITY
Inspiring Innovation.....

# Syllabus

## MASTER OF SCIENECE MATHEMATICS

**MMT1101: REAL ANALYSIS-I**
**Credit : 05**
**LTP 410**

**Course Description:**

The objective of this course is to demonstrate an understanding of the theory of sets, sequences and series, continuity, differentiation, and integration.

**Course learning outcomes:** Students will have an understanding of:

**CO1:** Appreciate how abstract ideas and regional methods in real analysis can be applied to important practical problems.

**CO2:** Identify challenging problems in real variable theory and find their appropriate solutions.

**CO3:** Deal with the axiomatic structure of metric spaces and generalize the concepts of sequences and series, and continuous functions in metric spaces.

**CO4:** Apply the knowledge of concepts of real analysis in order to study the theoretical development of different mathematical techniques and their applications.

**CO5:** Apply the monotone convergence theorem to prove the convergence of bounded monotone sequences.

**Course content:**

**Unit I**

Countable and uncountable sets. Metric spaces: Definition and examples, open sets, closed sets, compact sets, elementary properties of compact sets.

### Unit II

Compactness of k- cells, Compact subsets of Euclidean space Rk. Heine Borel theorem, Perfect sets, The Cantor set, Separated sets, connected sets in a metric space, connected subsets of real line.

### Unit III

Functions of Bounded Variation, Sequences in Metric Spaces: Convergent sequences (in Metric Spaces), sub sequences, Cauchy sequences, Complete metric spaces, Cantor's Intersection Theorem, Baire's theorem, Banach contraction principle.

### Unit IV

Continuity: Limits of functions (in metric spaces) Continuous functions, Continuity and Compactness, Continuity and Connectedness, Discontinuities, Monotonic functions, Uniform Continuity.

**Books Recommended:**

1. Walter Rudin, Principles of Mathematical Analysis (3rd Edition) McGraw-Hill Ltd.,
2. Simmons, G.F.; Introduction to Topology and Modern Analysis, McGraw- Hill Ltd. (App.1)
3. Shanti Narayan & P.K. Mittal; A Course of Mathematical Analysis.
4. S.C. Malik & Savita Arora; Mathematical Analysis, Wiley Eastern Ltd



## MMT1102: ALGEBRA-I

**Credits : 05**

**LTP 410**

**Course Description:**

The aim of this course is to introduce the students with groups, subgroups, Group homomorphism, isomorphism, direct product, Lagrange's theorem, and Sylow's theorems.

**Course learning outcomes:** After completion of this course, students will be able to:

**CO1:** Recognize the mathematical objects that are groups, and classify them as abelian, cyclic and permutation groups, etc.

**CO2:** Learn about automorphisms for constructing new groups from the given group.

**CO3:** Learn about the fact that external direct product and fundamental theorems.

**CO4:** Understand the concept of simplicity, commutator and group action.

### Unit I

Groups, Subgroups, Equivalence relations and partitions, generators and relations, homomorphisms, Cosets, Normal subgroups, Simple groups, Quotient groups, Group actions, Lagrange's theorem, Conjugate elements, the Class equation, Isomorphism theorems, Cyclic Groups, Cauchy's theorem.

### Unit II

Composition series, the Jordan Holder theorem, Groups of automorphisms, Inner automorphisms, Symmetric groups, Alternating groups, Sylow's theorems, p-groups.

### Unit III

Nilpotent groups, Simplicity of An $n \geq 5$, Cayley's theorem, the embedding theorem, Commutator subgroup, Characteristic subgroup, Solvable groups, Sequences of subgroups.

### Unit IV

Direct product and semi-direct product of groups, Fundamental theorem of finitely generated Abelian groups, Free groups, groups of symmetries, Groups of small order.

**BOOKS RECOMMENDED**:

1. Artin, M; Algebra, Prentice-Hall, 1991
2. Dummit, D.S.; Abstract-Algebra, John-Wiley & Sons, Students Edition- 1999 & Foote

3. Surjit Singh, and Zameerudin, Q; Modern Algebra.
4. J. Gallian.; Contemporary Abstract Algebra



## MMT1103: INTEGRAL TRANSFORMS AND INTEGRAL EQUATIONS

**Credits : 05**

**LTP 410**

**Course Description:**

The objective of this course is to transform maps the problem from its original domain into a new domain in which solution is easier as well as to provide a systematic mathematical treatment of the theory of integral transforms and its varied applications in applied mathematics and engineering. Also, to solve integrodifferential equations of Fredholm and Volterra type..

**Course learning outcomes:** After completion of this course, students will be able to:

**CO1:** demonstrate knowledge of a range of applications of these methods in Laplace and Fourier Transform.

**CO2:** To solve ordinary and partial differential equations with different forms of initial and boundary conditions.

**CO3:** develop their attitude towards problem-solving using Volterra equations.

**CO4:** solve the Fredholm equations by the method of successive approximations.

**Contents:**

**Unit I**

Laplace Transforms Laplace Transform, Properties of Laplace Transform, Inverse Laplace Transform, Convolution theorem, Laplace transform of periodic functions, unit step function and impulsive function, Application of Laplace Transform in solving ordinary and partial differential equations and Simultaneous linear equations.

**Unit II**

Fourier Transforms: Fourier transform, properties of Fourier transform, inversion formula, convolution, Parseval's equality, Fourier transform of generalized functions, application of Fourier transforms in solving heat, wave and Laplace equation. Fast Fourier transform.

**Unit III**

Volterra Equations: Integral equations and algebraic system of linear equations. Volterra equation L2 Kernels and functions. Volterra equations of first & second kind. Volterra integral equations and linear differential equations.

### Unit IV

Fredholm equations, solutions by the method of successive approximations. Neumann's series, Fredholm's equations with Pincherte-Goursat Kernel's

**BOOKS RECOMMENDED**:


1. Sneddon, I.N., The Use of Integral Transforms. McGraw Hill, 1985.
2. Goldberg, R.R., Fourier Transforms. Cambridge University Press, 1970.
3. Smith, M.G., Laplace Transform Theory. Van Nostrand Inc., 2000.
4. Elsegolc, L., Calculus of Variation. Dover Publications, 2010.
5. Kenwal, R.P., Linear Integral Equation; Theory and Techniques. Academic Press, 1971.
6. Hildebrand, F.B., Methods of Applied Mathematics (Latest Reprint). Dover Publications.
7. Pal, S. and Bhunia, S.C., Engineering Mathematics. Oxford University Press, 2015.




## MMT1104: COMPLEX ANALYSIS

**Credits : 05**

**LTP 410**

**Course Description:**

The aim of this course is to enable students to understand the complex-valued functions, principles of analytic functions, the line integral, and various fundamental theorems of complex analysis.

**Course learning outcomes:** After completion of this course, students will be able to:

**CO1:** identify curves and regions in the complex plane defined by simple expressions,

**CO2:** describe the basic properties of complex integration.

**CO3:** to compute such integrals, decide when and where a given function is analytic.

**CO4:** to understand the concept of transformations, fixed points, and cross-ratio**.**

**Contents:**

### Unit I

Functions of complex variables, limit, continuity, and differentiability, Analytic functions, Conjugate function, Harmonic function. Cauchy Riemann equations (Cartesian and Polar form). Construction of analytic functions.

### Unit II

Complex line integral, Cauchy's theorem, Cauchy's integral formula and its generalized form. Cauchy's inequality. Poisson's integral formula, Morera's theorem. Liouville's theorem. Power Series and its circle of convergence.

### Unit III

Taylor's theorem, Laurent's theorem Zeros and Singularities of an analytic function, Residue at a pole and at infinity, Cauchy's Residue theorem, Integration round unit circle, Evaluation of integrals of the type $\int \infty \infty f(x)dx$.

### Unit IV

Jordan's lemma, Fundamental theorem of algebra, Argument principle, Rouche's theorem, Conformal transformations, Bilinear transformations, critical points, fixed points, cross-ratio, Problems on cross-ratio and bilinear transformation.

**Books Recommended:**

1. Copson, E.T.; Theory of functions of complex variables.
2. Ahlfors, D. V.: Complex analysis.
3. Titchmarsh, E.C. Theory of functions of a complex variable.
4. Conway, J.B. Functions of one complex variable



## MMT1105: ORDINARY DIFFERENTIAL EQUATIONS AND SPECIAL FUNCTIONS

**Credits : 05**

**LTP 410**

**Course Description:** One of the course's main objectives is to familiarize the students with the fundamental concepts of Ordinary Differential Equations (ODE) and Special Functions, which will be used as background knowledge for the understanding of specialized courses in the field of Materials Science and Engineering that follow.

**Course learning outcomes:** After completion of this course, students will be able to:

**CO1:** Solve first and higher order differential equations utilizing higher-order techniques, Create and analyze mathematical models using higher order differential equations to solve higher-order problems.

**CO2:** Understand integral calculus and special functions of various engineering problems and to know the application of some basic mathematical methods via all these special functions.

**CO3:** Explain the applications and the usefulness of special functions.

**CO4:** Find power series solutions of differential equations and find recurrence relations and orthogonal properties.

**Contents:**

**Unit I**

Review of linear differential equations with constant & variable coefficients, Fundamental existence and uniqueness theorem for system and higher order equations (Picard's and Piano theorems), System of linear differential equations, an operator method for linear system with constant coefficients, Phase plane method.

**Unit II**

Homogeneous linear system with constant coefficients, Eigenvalues and eigen functions, orthogonality of eigen functions, Complex eigenvalues, repeated eigenvalues, Ordinary differential equations of the Sturm-Liouville problems, Expansion theorem, Extrema properties of the eigen values of linear differential operators, Formulation of the eigen value problem of a differential operator as a problem the of integral equation, Linear homogeneous boundary value problems.

**Unit III**

Power series solution of differential equations: about an ordinary point, solution about regular singular points, the method of Frobenius, Bessel equation and Bessel functions, Recurrence relations and orthogonal properties., Series expansion of Bessel Coefficients, Integral expression, Integral involving Bessel functions, Modified Bessel function, Ber and Bei functions, Asymptotic expansion of Bessel Functions, Legendre's differential equations, Legendre Polynomials , Rodrigue's formula, Recurrence relations and orthogonal properties.

**Unit IV**

The Hermite polynomials, Chebyshev's polynomial, Laugrre's polynomial: Recurrence relations, generating functions and orthogonal properties.

**Reference Books:**

1. Ross, S.L., Differential Equations, 3rd Edition. John Wiley & Sons, 2004.

2. Boyce, W.E. and Diprima, R.C., Elementary Differential Equations and Boundary Value problems, 4th Edition. John Wiley and Sons, 1986.

3. Sneddon, I.N., Special Functions of Mathematical Physics and Chemistry. Edinburg: Oliver & Boyd, 1956.

4. Bell, W.W., Special Functions for Scientists and Engineers. Dover, 1986.



**MMT2101: NUMBER THEORY**

**Credits : 05**

**LTP 410**

**Course Description:** The aim of this course is to effectively express the concepts and results of number theory, construct mathematical proofs of statements and find counterexamples to false statements in number theory.

**Course learning outcomes:** After completion of this course, students will be able to:

**CO1:** define the concept of arithmetic functions and their properties, Euler's Phi-function, and its properties.

**CO2:** interpret the concepts of divisibility, primitive roots for prime number, congruence, and number theorems.

**CO3:** understand the logic and concepts of Quadratic residues modulo a prime, Quadratic reciprocity law and methods behind the major proofs in number theory.

**CO4:** collect and use numerical data to form conjectures about the integers, apply appropriate concepts of finite and infinite continued fractions and their properties.

**Course content:**

**Unit I**

The sum of non-negative divisors of an integer, Number of divisors of an integer, Multiplicative functions, The Mobius function, Mobius Inversion formula, The greatest integer function, Euler's Phi-function and its properties.

**Unit II**

The order of an integer modulo n, primitive roots for primes, Composite Numbers having primitive roots, theory of indices and its applications to solving congruences.

**Unit III**

Quadratic residues modulo a prime, Euler's criterion, The Legendre symbol and its properties, Gauss Lemma, Quadratic reciprocity law, Jacobi's symbol and its properties, Pythagorean triplets, insolvability of the Diophantine Equations: $x^4 + y^4 = z^4$, $x^4 - y^4 = z^4$ in positive integers.

### Unit IV

Representation of an integer as a sum of two squares and the sum of four squares, Finite and Infinite continued fractions, convergent of a continued fraction and their properties, Pell's equation.

**Reference Books:**

1. David M. Burton: Elementary Number Theory, Mc Graw Hill 2002.

2. Hardy and wright: The Theory of Numbers.



## MMT2102: CLASSICAL MECHANICS

**Credits : 05**

**LTP 410**

**Course Description:** To apprise the students of Lagrangian and Hamiltonian formulations and their applications.

**Course learning outcomes:** After completion of this course, students will be able to:

**CO1:** necessity of Lagrangian and Hamiltonian formulations.

**CO2:** essential features of a problem (like motion under central force), use them to set up and solve the appropriate mathematical equations, and make quick and easy checks on the answer to catch simple mistakes.

**CO3:** theory of small oscillations which is important in several areas of physics e.g., molecular spectra, acoustics, vibrations of atoms in solids, coupled mechanical oscillators and electrical circuits.

**CO4:** use this rigid body dynamics, find an Euler's equation, Legendre transformation, canonical transformation.

**Course content:**

### Unit I

Newtonian Mechanics: One and many particle system; conservation of linear and angular momentum, work energy theorem, System of Particles: Constraints, D'Alembert principle, Principle of virtual work, Degree of freedom, generalized coordinates and momenta, Lagrange's equation and application of linear harmonic oscillator, Simple pendulum and central force problems, Cyclic coordinate, Symmetries and conservation laws, Hamiltonian, Lagrange's equation from Hamilton's Principle, Principle of least action derivation of equation of motion; variation and end points.

### Unit II

Central Force: Reduction of two body problem into single-body problems. Definition and characteristics of central force; Closure and stability of circular orbits. General analysis of orbits: bounded and unbounded orbits, Kepler's law of motion, Scattering in center of mass and laboratory frame of reference, Rutherford scattering.

### Unit III

Rigid Body Dynamics Euclerian angle, Inertia tensor, principal moment of inertia. Euler's equation of motion of a rigid body, Force free motion of a symmetrical top. Canonical Transformation: Canonical transformation, Legendre Transformation, Generating functions. Conditions for a transformation to be canonical, Hamilton-Jacobi equation, Hamilton's principle and characteristics functions, Action and action angle variables

### Unit IV

Wave Motion: Small oscillations, Normal modes and normal coordinates. Examples: Two coupled pendulums and Vibration of linear tri-atomic molecule, Dispersion relation.

**Reference Books:**

1. Rana, N.C. and Joag, P.S., Classical Mechanics, Tata McGraw-Hill, (1991).
2. Goldstein, H., Classical Mechanics, Pearson Education, (2007).

## MMT 2103: REAL ANALYSIS-II

**Credits : 05**

**LTP 410**

**Course Description:** To develop in a rigorous and self-contained manner the elements of real variable functions.

**Course learning outcomes:** After completion of this course, students will be able to:

**CO1:** Use the theory of Riemann-Stieltjes integral in solving definite integrals arising in different fields of science and engineering.

**CO2:** Understand integration from the theoretical point of view and apply its tools in different fields of applications.

**CO3:** Apply the knowledge of concepts of real analysis in order to study the theoretical development of different mathematical techniques and their applications.

**CO4:** Extend their knowledge of real variable theory for further exploration of the subject for going into research.

**Course content:**

### Unit I

The Riemann Stieltje's Integral: Definition and existence of Riemann Stieltje's integral, Properties of integral. Integration and Differentiation. Fundamental Theorem of Calculus, Ist and 2nd Mean Value Theorems of Riemann Stieltje's integral.

### Unit II

Integration of vector-valued functions, Sequence and Series of functions: Uniform Convergence, Uniform Convergence and continuity, Uniform Convergence and Integration, Uniform Convergence and Differentiation.

### Unit III

Equicontinuous families of functions, Arzela's Theorem, Weierstrass Approximation theorem. The stone-Weierstrass theorem.

### Unit IV

Power series: Radius of convergence, properties, Abel's Theorem, Taylor's Theorem Fourier series: Convergence, Riemann Lebesgue Lemma, Bessel's inequality, Parseval's Equality.

**Books Recommended:**

1. Walter Rudin; Principles of Mathematical Analysis (3rd edition) McGraw Hill Ltd.
2. S.C. Malik & Savita Arora.; Mathematical Analysis, Wiley Eastern Ltd.
3. Shanti Narayan & P.K. MittaL; A Course of Mathematical Analysis.
4. Apostol, T.M.; Mathematical Analysis 2nd Edition



**MMT 2104: ALGEBRA – II**

**Credits : 05**

**LTP 410**

**Course Description:** The aim of this course is to realize the importance of rings and modules as central objects in algebra and to study some applications.

**Course learning outcomes:** After completion of this course, students will be able to:

**CO1:** Learn about the fundamental concept of rings, integral domains, ring homomorphisms and isomorphisms theorems of rings.

**CO2:** Appreciate the significance of unique factorization in rings and various type of ideals.

**CO3:** Define Artinian and Noetherian modules (rings) and interpret some basic characterizations of them.

**CO4:** Explain modules and submodules, interpret all the properties of them.

**CO5:** Understand the structure theory of modules over a Euclidean domain along with its implications.

**Course content:**

**Unit I**

Rings, Subrings, Ideal, Factor Rings, Homomorphisms, Integral domains, Maximal and Prime Ideals, The field of quotients of an integral domain, Chinese Remainder Theorem, Simple Rings, Ideals of Matrix rings

**Unit II**

Principal Ideal domains, Euclidean rings, The ring of Gaussian Integers, Unique factorization domains, Gauss Lemma, Polynomial rings, Division algorithm, factorization in polynomial rings over unique factorization domains.

**Unit III**

Modules, submodules, free modules, quotient modules, Homomorphism theorems, direct sums, finitely generated modules, Simple modules, cyclic modules, differences between modules over rings and vector spaces..

**Unit IV**

Modules over PID's, structure theorem of modules over PID's, Torsion modules, Torsion free modules, Artinian and Noetherian Modules, Artinian and Noetherian rings, modules of finite length.

**Recommended Books:**

1. Fraleigh, J.B,: A finite course in Abstract Algebra 7th edition, Narosa Publishing House, New Delhi.
2. Singh, S. and Zameeruddin, Q.: Modern Algebra, Vikas Publishing House, New Delhi.
3. Dummit, D.S. and Foote, R.M.: Abstract Algebra, John-Wiley & Sons, Student Edition- 1999.
4. Bhattacharya, P.B., Jain, S.K., Nagpal, S.R.: Basic Abstract Algebra, Cambridge University Press, 1997.
5. Musili, C.: Rings and Modules, Narosa Publishing House, New Delhi, 1994.



## MMT2105: PARTIAL DIFFERENTIAL EQUATIONS

**Credits : 05**

**LTP 410**

**Course Description:**

The aim of this course is to introduce students to how to solve linear Partial Differential with different methods, to find the solutions of PDEs determined by conditions at the boundary of the spatial domain and initial conditions at time zero and to learn the technique of separation of variables to solve PDEs and analyze the behavior of solutions in terms of eigen function expansions.

**Course learning outcomes:** After completion of this course, students will be able to:

**CO1:** apply partial derivative equation techniques to predict the behavior of certain equations.

**CO2:** solve higher-order partial differential equations containing constant & variable coefficients.

**CO3:** Solve equations of the type of wave, Laplace & heat diffusion pertaining to engineering problems.

**CO4:** apply the concepts of partial differential equations in different wave formations with fixed ends & free ends.

**Contents:**

**Unit I**

First Order PDE: Partial differential equations; its order and degree; origin of first order PDE; determination of integral surfaces of linear first-order partial differential equations passing through a given curve; surfaces orthogonal to a given system of surfaces; non-linear PDE of first-order, Cauchy's method of characteristic; compatible system of first-order PDE; Charpit's method of solution, solutions satisfying given conditions, Jacobi's method of solution.

**Unit II**

**Second and Higher Order PDE:** Origin of second order PDE; linear second and higher order PDE with constant and variable coefficients; characteristic curves of the second order PDE; Monge's method of solution of non-linear PDE of second order.

### Unit III

**Separation of Variable Method:** Separation of variables for PDE; wave, diffusion, and Laplace equations and their solutions by Separation of variables method; Elementary solutions of Laplace equations.

### Unit IV

**Applications of PDE:** Vibrations governed by one and two-dimensional wave equations; vibrations of string and membranes; three-dimensional problems; diffusion equation; resolution of boundary value problems for diffusion equations and elementary solutions of diffusion equations.

**Recommended Books:**

1. Sneddon, I.N., Elements of Partial Differential Equation, 3rd Edition. McGraw Hill Book Company, 1998.
2. Copson, E.T., Partial Differential Equations, 2nd Edition. Cambridge University Press, 1995.
3. Strauss, W.A., Partial Differential Equations: An Introduction, 2nd Edition. 2007.
4. Sharma, J.N. and Singh, K., Partial differential equations for engineers and scientists, 2nd Edition. New Delhi: Narosa Publication House, 2009.



## MMT 3101: FUNCTIONAL ANALYSIS – I

**Credits : 05**

**LTP 410**

**Course Description:**

The aim of this course is to introduce students to the ideas and some of the fundamental theorems of functional analysis and give students a working knowledge of the basic properties of Banach spaces and bounded linear operators.

**Course learning outcomes:** After completion of this course, students will be able to:

**CO1:** Utilize the concepts of functional analysis, for example, continuous and bounded operators, normed spaces, to study the behaviour of different mathematical expressions arising in science and engineering.

**CO2:** They will be familiar with the natural embedding concepts and understand how it works in conjugate spaces.

**CO3:** Understand and apply fundamental theorems from the theory of normed and Banach spaces including the Hahn-Banach theorem, the open mapping theorem, the closed graph theorem, and the uniform boundedness theorem.

**CO4:** They will understand the general properties of linear operators and their dependencies on the type of functional spaces.

**CO5:** Explain the fundamental concepts of functional analysis and their role in modern mathematics.

**Course Contents:**

### Unit I

Normed linear spaces, Banach spaces, subspaces, quotient spaces. Continuous linear Transformations.

### Unit II

Equivalent norms. Finite dimensional normed linear spaces and compactness, Riesz Lemma, The conjugate space N*.

### Unit III

The Hahn-Banach theorem and its consequences. The natural embedding of N into N**, reflexivity of normed spaces. Open mapping theorem, projections on a Banach space, closed graph theorem, uniform boundedness principle.

**Unit IV**

Conjugate operators. Lp-spaces: Holder's and Minkowski's Inequalities, completeness of Lp-spaces.

**Reference Books:**

1. G.F. Simmons: Introduction to Topology and Modern Analysis, Ch. 9, Ch.10 (Sections 52-55), Mc. Graw-Hill International Book Company, 1963.

2. Royden, H. L.: Real Analysis, Ch 6 (Sections 6.1 -6.3), Macmillan Co. 1988.

3. Erwin Kreyszig: Introduction to Functional Analysis with Applications, John Wiley & Sons, 1978.

4. Balmohan V. Limaye: Functional Analysis, New Age International Limited.

5. P. K. Jain: Functional Analysis, New Age International (P) Ltd, Publishers, 2010.

## MMT 3102: DIFFERENTIAL GEOMETRY

**Credits : 05**

**LTP 410**

**Course Description:**

The aim of this course is to enable students to understand the fundamental theorem for plane curves, involutes and evolutes of space curves with the help of examples, to enable them to compute the curvature and torsion of space curves, coefficients and their derivatives.e.

**Course learning outcomes:** After completion of this course, students will be able to:

**CO1:** Explain the physical properties of different curves and spaces.

**CO2:** Understand principal directions and curvatures, asymptotic lines, and then apply their important theorems and results to study various properties of curves and surfaces.

**CO3:** Develop a facility to compute in various specialized systems, such as semi-geodesic coordinates or ones representing asymptotic lines or principal curvatures.

**CO4:** Understand the basic concepts and results related to space curves, tangents, normals and surfaces.

**Course Contents:**

**Unit I**

Curves in R3, a simple arc, curves and their parametric representation, arc length, Contact of curves, tangent line, osculating plane, curvature, principal normal, binormal, Normal Plane, rectifying plane.

**Unit II**

Curvature and torsion, Serret - Fernet Formula, Helics, Evolute and Involute of a parametric curve, Osculating circle and osculating sphere, spherical curves.

**Unit III**

Einstein's Summation Convention, Transformation of coordinates, tensor's law for transformation, Contravariant, covariant and mixed Tensors, addition, outer product, contraction, inner product and quotient law of tensors, Metric Tensor and Riemannian metric, Christoffel symbols, Covariant differentiation of tensors.

### Unit IV

Surfaces in R3, Implicit and Explicit forms for the equation of the surface, two fundamental forms of a surface, Family of surfaces, Edge of regression, Envelops, Ruled surface, Developable and skew surfaces, Gauss and Weingarten formulae.

**Recommended Books: -**

1. Pressley: Elementary Differential Geometry, Springer, 2005.
2. T. J. Willmore: Introduction to Differential Geometry
3. Martin M. Lipschutz: Differential Geometry
4. U.C. De; A.A. Shaikh & J. Sengupta: Tensor Calculus
5. M.R. Spiegel: Vector Analysis
6. D. Somasundaram: Differential Geometry – A First course, Narosa Publishing House



## MMT 3103: PROBABILITY THEORY

**Credits : 05**

**LTP 410**

**Course Description:**

The objective of this course is to enable students to define and identify some basic probability distributions/random variables.

**Course learning outcomes:** After completion of this course, students will be able to:

**CO1:** identify an appropriate probability distribution for a given discrete or continuous random variable.

**CO2:** use its properties to calculate probabilities.

**CO3:** Develop problem-solving techniques needed to accurately calculate probabilities.

**CO4:** Apply selected probability distributions to solve problems.

**Course Contents:**

### Unit I

A classical and axiomatic approach to the theory of probability, additive and multiplicative law of probability, conditional probability and Bayes theorem. Random variable, probability mass function, probability density function, cumulative distribution function, Distribution of functions of the random variable.

### Unit II

Two and higher dimensional random variables, joint distribution, marginal and conditional distributions, a bivariate and multivariate transformation of random variables Stochastic independence. Mathematical expectations, moments, moment generating function, characteristic function, Chebyshev's, and Cauchy Schwartz Inequality.

### Unit III

Discrete Distribution: Uniform, Binomial, Poisson, Geometric, Hyper geometric, Multinomial. Continuous Distributions: Uniform, Exponential, Normal distributions, Gamma distribution, Beta distribution.

### Unit IV

Chi-square distribution, t-distribution, F-distribution, sampling distribution of mean and variance of sample from a normal distribution. Convergence in probability and convergence in distribution, central limit theorem (Laplace theorem Linder berg, Levy's Theorem).

**Books Recommended:**

1. Hogg, R.V., Mckean, J.W. and Craig, A.T.: Introduction to Mathematical Statistics.
2. Rohtagi, V. K. and Ehsanes Saleh, A. K. Md. An Introduction to Probability and Statistics
3. Casella, G. and Berger, R. L.: Statistical Inference



## MMT 4101: TOPOLOGY

**Credits : 05**

**LTP 410**

**Course Description:**

The objective of this course is to introduce the concepts of Topology, Topological spaces, Connectedness, Hausdorff Space, Urysohn's Metrization Theorem, Completely normal spaces and some of their properties.

**Course learning outcomes:** After completion of this course, students will be able to:

**CO1:** Understand elementary properties of topological spaces and structures defined on them.

**CO2:** Construct maps between topological spaces

**CO3:** Ability to handle abstract ideas of Mathematics and Mathematical proofs.

**CO4:** Demonstrate an understanding of the concepts of metric spaces and topological spaces, and their role in mathematics.

**CO5:** Prove basic results about completeness, compactness, connectedness and convergence within these structures.

**Course Contents:**

**Unit I**

Topological spaces, Continuous functions, Homeomorphisms, Countability axioms, Topological groups.

**Unit II**

Connectedness, Intermediate value theorem and uniform limit theorem, Local connectedness.

**Unit III**

Compactness, Finite intersection property (F.I.P.), Cantor's intersection theorem, Uniform continuity, Bolzano-Weierastrass Property, and Local compactness. Metrizable topological spaces, The Tychonoff Theorem.

**Unit IV**

Separation axioms, Hausdorff spaces, Regular Spaces, Normal spaces, Urysohn's Lemma, Completely regular spaces, Urysohn's Metrization Theorem, The Tietze extension theorem, Completely normal spaces.

**BOOKS RECOMMENDED:**


1. J. R. Munkres: Topology, Prentice Hall of India, 2007 (Indian reprint)

2. J. L. Kelley : General Topology, 2008 (Indian reprint).

3. K. Janich, Topology, Springer-Verlag, 2004.




**MMT 4102: FUNCTIONAL ANALYSIS – I**

**Credits : 05**

**LTP 410**

**Course Description:**

The course covers basic functional analysis. The theory includes linear operators on Hilbert spaces, Inner product spaces. It also includes an introduction to the spectral theory for normal operators and its applications.

**Course learning outcomes:** After completion of this course, students will be able to:

**CO1:** understand the fundamentals of functional analysis and the concepts associated with the Hilbert spaces and Inner product spaces.

**CO2:** understand the fundamentals and concepts of conjugate spaces, and convergence in different spaces.

**CO3:** understanding of how these are used in mathematical applications in pure mathematics. ofs.

**CO4:** understand the concept of normal operators & linear operators in functional analysis.

**Course Contents:**

**Unit I**

Inner product spaces, Hilbert spaces, orthogonal complements, orthonormal sets.

**Unit II**

The conjugate space H*. Strong and weak convergence in finite and infinite dimensional normed linear spaces. Weak convergences in Hilbert spaces, weakly compact set in Hilbert spaces.

**Unit III**

The adjoint of an operator, self-adjoint operators, positive operators, normal operators, and Unitary operators. Projections on a Hilbert space.

**Unit IV**

Spectral Theorem for normal operators, Compact linear operators on normed spaces, properties of Compact linear operators.

**BOOKS RECOMMENDED:**

1. Simmons, G.F.: Introduction to Topology and Modern Analysis Ch.10 (Sections 56-59), Ch.11 (Sections 61-62), Mc Graw- Hill (1963) International Book Company.
2. Erwin Kreyszig: Introduction to Functional Analysis with Applications, John Wiley & Sons (1978).
3. Limaye, Balmohan V.: Functional Analysis, New Age International Limited, 1996.
4. Jain, P.K. & Ahuja, O.P.: Functional Analysis, New Age International (P) Ltd. Publishers, 2010.
5. Chandrasekhra Rao, K.: Functional Analysis, Narosa, 2002.
6. Somasundram, D.: A First Course in Functional Analysis, Narosa, 2006.



**MMT 4103: MEASURE THEORY**

**Credits : 05**

**LTP 410**

**Course Description:**

Students acquire the basic knowledge of measure theory needed to understand probability theory, statistics, and functional analysis.

**Course learning outcomes:** After completion of this course, students will be able to:

**CO1:** Knowledge and applications of basic concepts of measurable & non – measurable sets.

**CO2:** Understanding of characterizations & properties of measurable functions.

**CO3:** understanding the concept of Lebesgue Integral and its applications.

**CO4:** understand the concepts of different functions and theorems in measure theory.

Contents:

**Unit I**

Lebesgue Outer Measure, Measurable Sets, and their properties, Non-Measurable Sets, Outer and Inner Approximation of the Lebesgue Measurable Sets, Borel Sigma Algebra and The Lebesgue Sigma Algebra, Countable Additivity, Continuity, and the Borel-Cantelli Lemma.

**Unit II**

The motivation behind Measurable Functions, various Characterizations and Properties of Measurable functions: Sum, Product and Composition, Sequential Pointwise Limits and Simple Approximations to Measurable Functions. Littlewood's three Principles.

**Unit III**

Lebesgue Integral: Lebesgue Integral of a simple function and bounded measurable function over a set of finite measures. Comparison of Riemann and Lebesgue Integral. Bounded Convergence Theorem, Integral of a non-negative measurable function, Fatou's Lemma, Monotone convergence Theorem.

**Unit IV**

General Lebesgue Integral, Lebesgue Dominated Convergence Theorem, Countable Additivity and Continuity of Integration, Vitali Covers and Differentiability of Monotone Functions, Functions of Bounded Variation, Jordan's theorem, Absolutely Continuous

Functions, Absolute Continuity.

**Books Recommended:**

1. Royden, H.L. and Fitzpatrick: Real Analysis (Fourth Edition), Pearson Education Inc. New Jersey, U.S.A. (2010).

2. R. A. Gordon, The integrals of Lebesgue, Denjoy, Perron and Henstock, Amer. Math. Soc. Province, RI, (1994).

3. Barra, G De.: Introduction to Measure Theory, Van Nostrand and Reinhold Company.

4. Jain, P.K. and Gupta, V.P.: Lebesgue Measure and Integration.



## MMT 3104: OPERATIONS RESEARCH-I

**Credits : 05**

**LTP 410**

**Course Description:**

The course aims at building capabilities in the students for analyzing different situations in the industrial/ business scenario involving limited resources and finding the optimal solution within constraints.

**Course learning outcomes:** After completion of this course, students will be able to:

**CO1:** Analyze any real-life system with limited constraints and depict it in a model form.

**CO2:** Convert the problem into a mathematical model.

**CO3:** Solve the mathematical model manually as well as using soft resources/software.

**Contents:**

**Section-A**

Mathematical formulation of linear programming problem, properties of a solution to the linear programming problem, generating extreme point solution, simplex computational procedure, development of minimum feasible solution, the artificial basis techniques, a first feasible solution using slack variables.

**Section-B**

Two phase and Big-M method with artificial variables, General Primal-Dual pair, formulating a dual problem, primal-dual pair in matrix form, Duality theorems, complementary slackness theorem, duality and simplex method, economic interpretation of primal-dual problems.

**Section-C**

The General transportation problem, transportation table,
duality in transportation problem, loops in transportation tables, linear programming formulation, solution of transportation problem, test for optimality, degeneracy, transportation algorithm (MODI method), time minimization transportation problem..

**Section-D**

Assignment Problems: Mathematical formulation of assignment problem, the assignment method, typical assignment problem, the traveling salesman problem. Game Theory: Two-person zero sum games, maximin-minimax principle, games without saddle points (Mixed strategies), graphical solution of 2×n and m×2 games, dominance property, arithmetic method of n×n games, general solution of m×n rectangular games.

**BOOKS RECOMMENDED:**

1. Gass, S. L.: Linear Programming
2. Hadley, G.: Mathematical Programming
3. Kambo, N. S.: Mathematical Programming
4. Kanti Swarup, Gupta, P.K. & Man Mohan: Operations Research
5. R. Panneerselvam: Operations Research
6. Taha, H.A.: Operations Research



## MMT 3105: DISCRETE MATHEMATICS-I

**Credits : 05**

**LTP 410**

**Course Description:**

Students will learn basic Logic and Set theory, Boolean Algebra and Lattices and core ideas in Graph theory.

**Course learning outcomes:** After completion of this course, students will be able to:

**CO1:** Write an argument using logical notation and determine if the argument is or is not valid.

**CO2:** Demonstrate the ability to write and evaluate a proof or outline the basic structure of and give examples of each proof technique described.

**CO3:** Demonstrate different traversal methods for trees and graphs.

**CO4:** Demonstrate the concept of morphism in computing using different diagrams and algorithms.

**Contents:**

**Section-A**

Mathematical Logic: Properties and logical operations, Truth function, Logical connections, logically equivalent statements, tautology and contradiction, algebra of proposition, arguments, duality law, Quantifiers, inference rules for quantified statements, predicates calculus, interference theory of predicate logic, valid formula involving quantifiers.

**Section-B**

Boolean Algebra: Boolean Algebra and its properties, Principle of duality in Boolean Algebra, Algebra of Classes, Isomorphism, Partial Order, Boolean switching circuits, Equivalence of two circuits, simplification of circuit, Boolean polynomial, Boolean expression & function, Fundamental forms of a Boolean function. Disjunctive normal form, Complement function of a Boolean function..

**Section-C**

Lattices: Partial ordered sets, Hasse diagrams, isomorphism, External elements of practically ordered set, lattices, lattices as algebraic system, sub-lattices, direct product and homomorphism

Section-D

Graph Theory: Simple Graphs, Incidence and degree, regular graph, isolated vertex, pendent vertex, Null graph, Diagraph, isomorphism's, Eulerian graph, planner and dual graph, planner graph representations, Thickness and crossing numbers, Adjancy matrix, incident matrix, cycle matrix.

**BOOKS RECOMMENDED:**

1. Trambley, J.P. and Manohar, R: Discrete Mathematical Structures with Applications to Computer Science.

2. Liu C.L.: Elements of Discrete Mathematics.

3. Alan Doerr and Kenneth Levasseur: Applied Discrete Structures for Computer Science



**MMT 3106: FLUID DYNAMICS**

**Credits : 05**

**LTP 410**

**Course Description:**

To give fundamental knowledge of fluid, its properties and behavior under various conditions of internal and external flows and to understand about application of mass, momentum, and energy equation in fluid flow.

**Course learning outcomes:** After completion of this course, students will be able to:

**CO1:** stress-strain relationship in fluids,

**CO2:** classify their behavior and also establish force balance in static systems.

**CO3:** dimensionless groups that help in scale-up and scale-down of fluid flow systems.

**Contents:**

**Section-A**

Inviscid Flows: Introduction to fluid flows, equation of continuity, Euler's equation of motion, Bernoulli's equation, steady motion under conservative body forces, potential theorems.

**Section-B**

Viscous Flows: Newtonian fluids, convective momentum transport, shell momentum balances and boundary conditions, use of shell momentum balance to solve laminar flow problems: flow of a falling film, flow through a circular tube (Hagen-Poiseuille flow), flow through an annulus, flow of two adjacent immiscible fluids, creeping flow around a sphere.

**Section-C**

The Navier-Stokes Equation: The Navier-Stokes equation, use of the Navier-Stokes equation in solving the following flow problems: Steady flow in a long circular cylinder, falling film with variable viscosity, The Taylor-Couette flow, Plane Couette flow; Shape of the surface of a rotating liquid, Flow near a slowly rotating sphere.

**Section-D**

Steady viscous flow in tubes of uniform cross sections, viscous flow past a fixed sphere, Dimensional analysis of fluid motion, Prandtl boundary layer, Time dependent flows of Newtonian fluids.

Section-D

Steady viscous flow in tubes of uniform cross sections, viscous flow past a fixed sphere, Dimensional analysis of fluid motion, Prandtl boundary layer, Time dependent flows of Newtonian fluids.

**BOOKS RECOMMENDED:**

1. F. Charlton, Textbook of Fluid Dynamics 1st Edition.

2. R. B. Bird, W. E. Stewart, E. Lightfoot, Transport Phenomena, 2nd Edition.

3. L. D. Landau and E. M. Lifshitz, Fluid Mechanics, 3rd Edition.



**MMT3107: ADVANCED NUMERICAL ANALYSIS**

**Credits : 05**

**LTP 410**

**Course Description:**

With this overall aim, the course strives to enable students to: Understand analytical, developmental and technical principles that relate to Numerical Methods for solving Differential Equations, and Numerical Optimization, develop the academic abilities required to solve problems.

**Course learning outcomes:** After completion of this course, students will be able to:

**CO1:** Choose, develop and apply the appropriate numerical techniques for different problems,

**CO2:** Interpret the results and assess accuracy.

**CO3:** trace the curve for linear & nonlinear equations.

**CO4:** work on the problems of finite elements using different methods for ODE's & PDE's.

**Contents:**

**Section-A**

Finite difference approximation to partial derivatives, parabolic equations: Transformation to non-dimensional forms, an explicit method, Crank Nicolson Implicit method, solution of implicit equations by Gauss Elimination, derivative boundary conditions, local truncation error, Consistency, Convergence and stability.

**Section-B**

Iterative methods for elliptic equations, Jacobi's method, Gauss-Siedel method, S.O.R. method, Residual method. Hyperbolic equations: Implicit difference methods for wave equation, Stability Analysis, Lax, Wendroff explicit method on rectangular mesh for 1st order equations, second order quasi-linear Hyperbolic equations,

**Section-C**

Least squares curve fitting for straight line and nonlinear curves, Orthogonal polynomials, Gram Schmidt Orthogonalization process.

**Section-D**

Finite element methods: Rayleigh Ritz Method, Collocation and Galerkin's Method, Finite element methods for ODE's., finite element methods for one dimensional and two-dimensional problems, Introduction to F. E. M. for partial differential equations.

**BOOKS RECOMMENDED:**

1. G. D. Smith: Numerical Solution of Partial Differential Equations.
2. S.S. Sastry : Introductory Methods of Numerical Analysis.
3. J. N. Reddy: An Introduction to Finite Element Methods.



**MMT3108: STOCHASTIC PROCESS**

**Credits : 05**

**LTP 410**

**Course Description:**

The course will consider Markov processes in discrete and continuous time. The theory is illustrated with examples from operation research, biology and economy.

**Course learning outcomes:** After completion of this course, students will be able to:

**CO1:** Define basic concepts from the theory of Markov chains and present proofs for the most important theorems.

**CO2:** Compute probabilities of transition between states and return to the initial state after long time intervals in Markov chains.

**CO3:** compute birth & death values using different process and distributions.

**Contents:**

**Section-A**

Introduction to stochastic processes, classification of stochastic processes according to state space and time domain. Countable state Markov Chains, Chapman-Kolmogorov equations, calculations of n-step transition probability and its limit.

**Section-B**

Stationary distribution, classification of states. Random walk model, gambler's ruin problem. Discrete state space continuous time Markov Chains: Kolmogorov-Feller differential equations.

**Section-C**

Poisson process, Simple birth process, Simple death process. Recurrent events, recurrence time distribution,

**Section-D**

Necessary and sufficient condition for persistent and transient events and their illustrations, delayed recurrent event. Discrete branching process, mean and variance of the n-th generation, probability of extinction.

**BOOKS RECOMMENDED:**

1. Feller, W.: Introduction to Probability Theory and its Applications, Vol. 1.
2. Hoel, P.G., Port, S.C. and Stone, C.J.: Introduction to Stochastic Processes.
3. Karlin, S. and Taylor, H.M.: A First Course in Stochastic Processes, Vol. 1.
4. Medhi, J.: Stochastic Processes.
5. Bailey, N.T.J.: The Elements of Stochastic Processes.
6. Adke, S.R. and Manjunath, S.M.: An Introduction to Finite Markov Processes.



## MMT3109: COMMUTATIVE ALGEBRA

**Credits : 05**

**LTP 410**

**Course Description:**

The course develops the theory of commutative rings, ideals in commutative rings, chain conditions for ideals, localization of commutative rings, modules over commutative rings and numerical invariants of commutative rings and modules.

**Course learning outcomes:** After completion of this course, students will be able to:

**CO1:** know the definition of commutative rings, local rings, prime and maximal ideals, and modules over commutative rings.

**CO2:** know how to localize rings and modules and are familiar with important applications of localization.

**CO3:** know the Hilbert Null stellensatz.

**CO4:** learn the concepts of valuation of rings, going up and going down theorems.

**Contents:**

**Section-A**

Prime ideals and maximal ideals in commutative rings, Nilradical, Jacobson radical, Operations on ideals, Extension and contraction of ideals, Nakayama lemma, Exact sequences of modules.

**Section-B**

Injective modules, Projective modules, Tensor product of modules, restriction and extension of scalars, Exactness properties of the tensor product, flat modules.

**Section-C**

Rings and Modules of fractions, Localization, Local properties, extended and Contracted ideals in rings of fractions, Primary decomposition, Integral dependence, integrally closed domains, Zariski topology, The Null stellensatz.

**Section-D**

The going up theorem, the going down theorem, valuation rings, rings with chain conditions, discrete valuation rings, Dedekind domains, fractional ideals.

**BOOKS RECOMMENDED:**

1. Atiyah, M.F. and Macdonald, I.G.: Introduction to Commutative Algebra
2. Matsumura, H.: Commutative Ring Theory
3. Reid, M: Undergraduate Commutative Algebra
4. Jacobson, N: Basic Algebra-II, Dover Publications, Inc.
5. Gopalakrishnan, N.S.: Commutative Algebra



**MMT3110: THEORY OF WAVELETS**

**Credits : 05**

**LTP 410**

**Course Description:**

The objective of this course is to cover the basic theory of wavelets, construction of scaling functions, bases, frames and their applications in various scientific problems.

**Course learning outcomes:** After completion of this course, students will be able to:

**CO1:** understand the properties of various scaling functions and their wavelets.

**CO2:** understand the properties of multiresolution analysis.

**CO3:** implement wavelets in various problems like image compression, denoising etc.

**Contents:**

**Section-A**

Orthonormal systems and basic properties, Trigonometric system, Walsh orthonormal system, Haar system.

**Section-B**

Generalization of Orthonormal system (Frames and Riesz basis) and their examples. Introduction to wavelets: Definition and examples of continuous and discrete wavelet transforms.

**Section-C**

Multi-resolution analysis, Properties of translation, dilation and rotation operators, Wavelet and scaling series.

**Section-D**

Wavelets and signal analysis, Denoising, Representation of signals by frames.

**BOOKS RECOMMENDED:**

1. D.F. Walnut, An Introduction to Wavelet Analysis, Birkhauser, Boston, Basel 2000.
2. F. Schipp, W.R. Wade and P. Simon, Walsh Series: An Introduction to Dyadic Harmonic Analysis, Adam Hilger, Bristol, New York 1990.
3. O. Christensen, An Introduction to Frames and Reisz Bases, Birkhauser, Basel 2008.
4. K.P. Soman & K.I. Ramachandran. Insight into Wavelets: From Theory to Prachce, Prentice Hall of India, 2008.

**MMT3111: FOURIER ANALYSIS**

**Credits : 05**

**LTP 410**

**Course Description:**

The goals for the course are to gain a facility with using the transform, both specific techniques and general principles, and learning to recognize when, why, and how it is used. .

**Course learning outcomes:** After completion of this course, students will be able to:

**CO1:** understand the concept & properties of Fourier series.

**CO2:** under the concept and applications of Fourier transform.

**CO3:** Understand the concept & applications of convergence of Fourier series.

**CO4:** Understand the applications of Fourier transforms of derivatives & integrals.

**Contents:**

**Section-A**

Trigonometric Series, Basic Properties of Fourier Series, Riemann-Lebesgue Lemma, The Dirichlet and Fourier Kernels, Continuous and Discrete Fourier Kernels.

**Section-B**

Lebesgue's pointwise, convergence theorem. Finite Fourier Transforms, Convolutions, the exponential form of the Lebesgue's theorem.

**Section-C**

Pointwise and Uniform, Convergence of Fourier Series. Cesaro and Abel Summability. Fejer's Kernel, Fejer's theorem, a continuous function with divergent Fourier series, term wise integration, term wise differentiation,

**Section-D**

The Fourier Transforms and Residues, inversions of the trigonometric and exponential forms, Fourier Transformations of derivatives and integrals.

**BOOKS RECOMMENDED:**

1. R. Strichartz, A Guide to Distributions and Fourier Transforms, CRC Press.

2. E.M. Stein and R. Shakarchi, Fourier Analysis: An Introduction, Princeton University Press, Princeton 2003.



**MMT3112: TOPICS IN LINEAR ALGEBRA**

**Credits : 05**

**LTP 410**

**Course Description:**

The goals for the course are to gain a facility with using the transform, both specific techniques and general principles, and learning to recognize when, why, and how it is used. .

**Course learning outcomes:** After completion of this course, students will be able to:

**CO1:** Analyze the structure of real-world problems and plan solution strategies. Solve the problems using appropriate tools.

**CO2:** Enhance and reinforce the student's understanding of concepts through the use of technology when appropriate.

**Contents:**

**Section-A**

Generalized eigen vectors of a linear operator, direct sum decomposition of a finite dimensional vector space V over an algebraically closed field into generalized eigen spaces of a linear operator on V, Jordan chains, Jordan basis, Nilpotent operators on finite dimensional vector spaces, Existence and uniqueness of Jordan form for nilpotent operators on finite dimensional vector space over any field, existence and uniqueness of Jordan form for any operator on finite dimensional vector spaces over the field of complex numbers, Jordan form for linear operators on finite dimensional vector space over reals.

**Section-B**

Semi-simple operators, cyclic spaces, cyclic decompositions, existence, and uniqueness of rational canonical form for any linear operator on a finite dimensional vector space over any field. Bilinear forms, matrix representation of a bilinear form w.r.t an ordered basis, vector space of all bilinear forms on a vector space, symmetric bilinear forms, functional and bilinear forms, radicals of a bilinear form, degenerate and non-degenerate bilinear forms, diagonalizable bilinear forms, quadratic forms, rank and signature of bilinear forms, Sylvestor's law of inertia.

**Section-C**

positive definite, positive semi-definite, negative definite and negative semi-definite matrices and various characterizations for positive definiteness/negative definiteness of a matrix, Principle axis transformation of quadratic forms, classification of quadrics in three dimensional Euclidean space, Hermitian forms, The second derivative test for maxima and minima of functions of several variables using quadratic forms, Multilinear products, The tensor algebra, The exterior algebra.

**Section-D**

Determinant as n-linear function, its properties, characterizations and uniqueness of determinant function, determinant as n-dimensional volume of the parallelepiped, Some applications of linear algebra: finite symmetry groups in three dimensions, applications of linear algebra in solving differential equations, sum of squares and Hurwitz's theorem, linear codes, linear codes defined by generating matrices, The ISBN, Hamming codes, Hadamard codes, Perfect linear codes.

**BOOKS RECOMMENDED:**

1. Linear Algebra by Charles W. Curtis.
2. Fundamentals of Linear Algebra by James B. Carrell.
3. Linear Algebra by Kenneth Hoffman and Ray Kunze.
4. Linear Algebra by Vivek Sahai and Vikas Bist.
5. Linear Algebra by Friedberg, Insel and Spence.



## MMT3113: TOPOLOGICAL VECTOR SPACES

**Credits : 05**

**LTP 410**

**Course Description:**

To train the students in the domain of Topology and to give sufficient knowledge of the subject which can be used by student for further applications in their respective domains of interest .

**Course learning outcomes:** After completion of this course, students will be able to:

**CO1:** familiar with the Subspace, product space of a topological vector space.

**CO2:** familiar with the quotient space of a topological vector space.

**CO3:** familiar with the complete topological vector spaces.

**CO4:** familiar with the applications of complete topological vector spaces & Frechet spaces to covering spaces.

**Contents:**

**Section-A**

Definition and examples of topological vector spaces. Convex, balanced, and absorbing sets and their properties. Minkowski's functional.

**Section-B**

Subspace, product space and quotient space of a topological vector space.

**Section-C**

Locally convex topological vector spaces. Normable and metrizable topological vector spaces.

**Section-D**

Complete topological vector spaces and Frechet space. Linear transformations and linear functional and their continuity

**BOOKS RECOMMENDED:**

1. Walter Rudin: Functional Analysis, TMH Edition, 1974.
2. Schaefer, H.H.: Topological Vector Spaces, Springer, N.Y., 1971.

## MMT3114: COMPUTER PROGRAMMING WITH C

**Credits : 05**

**LTP 402**

**Course Description:**

The course is designed to provide complete knowledge of C language. Students will be able to develop logics which will help them to create programs, applications in C. Also, by learning the basic programming constructs they can easily switch over to any other language in future.

**Course learning outcomes:** After completion of this course, students will be able to:

**CO1:** Able to implement the algorithms and draw flowcharts for solving Mathematical and Engineering problems.

**CO2:** Demonstrate an understanding of computer programming language concepts. To be able to develop programs on Linux platform.

**CO3:** Able to design and develop Computer programs, analyzes, and interprets the concept of pointers, declarations, initialization, operations on pointers and their usage.

**Contents:**

**Section-A**

Basic Structure of C-Program, Constants, variables, Data types, Assignments, console I/O statements, Arithmetical, Relational and logical operators, Control statements: if, switch.

**Section-B**

While do while, for, continue, go to and break. Function definition and declaration, Arguments, return values and their types, Recursion. One and two-dimensional arrays, Initialization, Accessing array elements, Functions with arrays.

**Section-C**

Address and pointer variables, declaration and initialization, pointers and arrays, pointers and functions.,

**Section-D**

Structure initialization, structure processing, nested structure, Array of structures, structure and functions. Union. Defining and opening a file, closing a file, Input/Output operations on files.



Practical: Based on implementation of Numerical and Statistical Techniques Using C Language.

Solution to nonlinear equations, a system of linear equations; Numerical integration, Solution to ordinary differential equations. Measures of central tendency, Correlation and Regression.

**BOOKS RECOMMENDED:**

1. Byron S. Gottrfried: Programming with C (Schaum's outline series).
2. Stan Kelly-Bootle: Mastering Turbo C.
3. Brain Kernighan & Dennis Ritchi: The C Programming Language.
4. Yashavant Kanetkar: Let us C.
5. E Balagurusamy: Programming in ANSI C.
6. R.S. Salaria: Application Programming in C.

**MMT3115: OPERATIONS RESEARCH-II**

**Credits : 05**

**LTP 410**

**Course Description:**

The purpose of the course is to provide students with the concepts and tools to help them understand the operations research and mathematical modeling methods. These methods will help the students to solve economic issues, which help to make a decision.

**Course learning outcomes:** After completion of this course, students will be able to:

**CO1:** Be able to solve simple problems of replacement and implement practical cases of decision making under different business environments.

**CO2:** Be able to design and solve simple models of CPM and queuing to improve decision making and develop critical thinking and objective analysis of decision problems.

**Contents:**

**Section-A**

**Queueing Theory:** Introduction, Queueing System, elements of queueing system, distributions of arrivals, inter arrivals, departure service times and waiting times. Classification of queueing models, Queueing Models: (M/M/1): (∞/FIFO), (M/M/1): (N/FIFO), Generalized Model: Birth- Death Process, (M/M/C): (∞/FIFO), (M/M/C) (N/FIFO).

**Section-B**

**Inventory Control:** The inventory decisions, costs associated with inventories, factors affecting Inventory control, Significance of Inventory control, economic order quantity (EOQ), Deterministic inventory problems without shortage and with shortages, EOQ problems with price breaks, Multi item deterministic problems.

**Section-C**

Replacement Problems: Replacement of equipment/Asset that deteriorates gradually, replacement of equipment that fails suddenly, Mortality Theorem, recruitment and promotion problem, equipment renewal problem.

**Section-D**

Simulation: Need of simulation, methodology of simulation. Simulation models, event- type simulation, generation of random numbers, Monte Carlo simulation. Simulation of inventory problems, queuing system, maintenance problems and job sequencing.

**BOOKS RECOMMENDED:**

1. R. Panneerselvam: Operations Research

2. Taha, H.A.: Operations Research

3. Chandra sekhara, Rao & Shanti Lata Mishra: Operations Research

4. Kanti Swarup, Gupta, P.K. & Man Mohan: Operations Research

5. Mustafi, C.K.: Operations Research

**MMT3116: DISCRETE MATHEMATICS-II**

**Credits : 05**

**LTP 410**

**Course Description:**

The purpose of the course is to provide students with the concepts and tools to help them understand the operations research and mathematical modeling methods. These methods will help the students to solve economic issues, which help to make a decision.

**Course learning outcomes:** After completion of this course, students will be able to:

**CO1:** specify and manipulate basic mathematical concepts such as graph theory containing trees and algorithms.

**CO2:** understand & solve problems related to graph theory containing directed, undirected & flow matrix.

**CO3:** solve the problems related to recurrence relations.

**CO2:** apply basic counting techniques to solve combinatorial problems.

**Contents:**

**Section-A**

Graph Theory: Tree, rooted tree, binary tree, spanning trees, minimal spanning tree, kruskal's algorithm, Chromatic number, four-column problem, Chromatic Polynomi**als.**

**Section-B**

Directed Graphs: Directed paths, directed cycles, acyclic graph, network flow, Max flow, min cut theorem, K-flow**.**

**Section-C**

Recurrence relation & Generating functions: Order & Degree of recurrence relation, telescopic form, recursion theorem, solution of linear recurrence relation, Homogenous solution, closed form expression, generating function, solution of recurrence relation using generating function.

**Section-D**

Combinatorics: Principle of Mathematics Induction, the basic of counting, inclusion and exclusion principle, pigeonhole principles, Polya's counting theorem.



**BOOKS RECOMMENDED:**

1. Trambley, J.P. and Manohar, R: Discrete Mathematical Structures with Applications to Computer Science.

2. Liu C.L.: Elements of Discrete Mathematics.

3. Alan Doerr and Kenneth Levasseur: Applied Discrete Structures for Computer Science

4. Narsingh Deo: Graph Theory with Applications to Engineering and Computer Sciencesch

**MMT3117: BANACH ALGEBRA AND OPERATOR THEORY**

**Credits : 05**

**LTP 410**

**Course Description:**

The course is aimed at proving the spectral theorem for normal operators on Hilbert space. Along the way, students will be exposed to many ideas and tools that are useful in other branches of analysis and mathematical physics, including spectrum and commutative Banach algebras and their properties.

**Course learning outcomes:** After completion of this course, students will be able to:

**CO1:** Find the maximal spectra of concrete commutative Banach algebras.

**CO2:** Find the essential spectra of linear operators.

**CO3:** Describe the functional calculi and the spectral decompositions of concrete self-adjoint operators.

**Contents:**

**Section-A**

**Banach Algebras:** Definitions and simple examples. Regular and singular elements. Topological divisors of zero, Spectrum of an element of a Banach Algebra, formula for spectral radius..

**Section-B**

**Compact and Bounded Operators:** Spectral properties of compact linear operators, spectral properties of bounded linear operators, operator equations involving compact linear operators

**Section-C**

Spectral radius of a bounded linear operator. Spectral properties of bounded self-adjoint linear operators on a complex Hilbert space. Positive operators.

**Section-D**

Monotone sequence theorem for bounded self-adjoint operators on a complex Hilbert space. Square roots of a positive operator. Projection operators, Properties of projection operators.



**BOOKS RECOMMENDED:**

1. Simmons, G.F.: Introduction to Topology and Modern Analysis (Section 6.4-6.8), Mc Graw-Hill (1963) International Book Company.

2. Kreyszig, E. Introductory Functional Analysis with Applications, (Sections 8.1-8.5, 9.1-9.6) John Wiley & Sons, New York, 1978.

**MMT3118: FINANCIAL DERIVATIVES**

**Credits : 05**

**LTP 410**

**Course Description:**

This course aims at providing an in-depth understanding of financial derivatives in terms of concepts, structure, instruments and trading strategies for profit and risk management.

**Course learning outcomes:** After completion of this course, students will be able to:

**CO1:** the theoretical valuation principles and basic risk measures,

**CO2:** the strengths and weakness of different valuation techniques and risk measures as well as

**CO3:** providing ability to apply valuation and risk management techniques in practical examples.

**CO4:** concept of derivations of different equations using mathematical

**Contents:**

**Section-A**

Products and Markets: Time Value of money, Periodic and Continuous compounding Commodities, equities Currencies, Indices, Fixed income securities, Derivatives: Basic Concepts, Pay-off diagrams, Risk and Return.

**Section-B**

One step Binomial model. Random behavior of assets, Time scales, Wiener Process. Forwards contracts and future contracts. Options, call and Put options, Put-call parity, Bounds on Option Prices, European and American calls.

**Section-C**

Elementary Stochastic Calculus: Motivation and examples, Brownian Motion, Mean Square limit. Ito's Lemma, Some Pertinent examples, Black Scholes Model: Arbiterage.

**Section-D**

The derivation of Black Schole, Partial differential equation, Reduction of Black Scholes equation to diffusion equation, Numerical solutions of Black Scholes equation.



**Recommended Books:**

1. M. Capinski and T. Zastawniak: Mathematics for Finance: An Introduction to Financial Engineering, Springer

2. P. Wilmott: The Theory and Practice of Financial Engineering, John Willey and Sons, London, 1998.

3. P. Wilmott, Sam Howison and Jeff Dewynne: The Mathematics of Financial Derivatives, Cambridge University Press, 1995.

**MMT3119: THEORIES OF INTEGRATION**

**Credits : 05**

**LTP 410**

**Course Description:**

The aim of this course is to learn the basic elements of Lebesgue integral, The Darboux integral and their applications, the fundamental theorems of Calculus for the gauge integrals and its consequences and Locally and globally small Riemann sums and their equivalence.

**Course learning outcomes:** After completion of this course, students will be able to:

**CO1:** provide the participants with an understanding of the different types of integrals and

**CO2:** provide skills to evaluate & derive different lemma's & proofs of the theorems.

**CO3:** provide skills to understand the concept of relationship between different functions.

**CO4:** provide skills to solve different types of integrals involving Riemann, Denjoy, Perron & McShane.

**Contents:**

**Section-A**

The need to extend the Lebesgue integral, The Darboux integral, necessary and sufficient conditions for Darboux integrability, the equivalence of the Riemann and Darboux integrals, tagged divisions and their use in elementary real analysis, Cousin's lemma, the Henstock-Kurzweil and McShane integrals.

**Section-B**

Saks-Henstock Lemma, the fundamental theorems of Calculus for the gauge integrals and its consequences. The Squeeze theorem regulated functions and their integrability, Convergence theorems for the gauge integrals, the Hake's Theorem, The McShane integral Vs Lebesgue integral.

**Section-C**

Extensions of Absolute Continuity and Bounded variation, the relationship between the function classes ACG*, ACG\delta, BVG* and BVG\delta, the Denjoy and Perron integrals.

**Section-D**

Locally and globally small Riemann sums and their equivalence, The class of Henstock-Kurzweil integrable functions, advantages of the Henstock-Kurzweil integral over Riemann, Lebesgue, Denjoy, Perron and McShane integrals.

**BOOKS RECOMMENDED:**


1. R. A. Gordon, The Integrals of Lebesgue, Denjoy, Perron and Henstock, Amer. Math. Soc. Province, RI, (1994).
2. R.G. Bartle, A Modern Theory of Integration, Graduate Studies in Mathematics, 32. Amer. Math. Soc., Province, RI (2001).
3. D. S. Kurtz; C. W. Schwatz, Theories of Integration, the Integrals of Riemann, Lebesgue, Henstock-Kurzweil and McShane, Series in Real Analysis 9, World Scientific Publishing Co., Inc., NJ, (2004).
4. P. Y. Lee; R. Vyborny, Integral: An Easy Approach after Kurzweil and Henstock, Aus. Math. Soc. Lecture Series 14. Cambridge University Press, Cambridge, (2000).

## MMT3120: ALGEBRAIC TOPOLOGY

**Credits : 05**

**LTP 410**

**Course Description:**

The aim of this course is to learn the basic elements of manifolds, Weak and free products of groups and covering spaces.

**Course learning outcomes:** After completion of this course, students will be able to:

**CO1:** Knowledge of fundamental concepts and methods in algebraic topology, in particular singular homology.

**CO2:** Skills to apply his or her knowledge of algebraic topology to formulate and solve problems of a geometrical and topological nature in mathematics.

**Contents:**

**Section-A**

N-manifolds, orientable vs non orientable manifolds, Compact-connected 2-manifolds, Classification theorem for compact surfaces, Triangulations of compact surfaces, The Euler characteristic of a surface, Fundamental group of a space, Fundamental group of Circle and product spaces, The Brouwer fixed point theorem in dimension 2, Homotopy type and Homotopy Equivalence of Spaces.

**Section-B**

Weak products of abelian groups, free abelian groups, free products of groups, free groups.

**Section-C**

The Seifert Von Kampen theorem and its applications, Structure of the fundamental group of a Compact surface.

**Section-D**

Covering Spaces: Lifting of paths to covering spaces, The fundamental group of a covering space, Homomorphism and automorphisms of covering spaces, Regular covering spaces and Quotient spaces, The Borsuk-Ulam theorem for 2-sphere, The existence theorem for covering spaces.



**BOOKS RECOMMENDED:**

1. W.S. Massey. A Basic Course in Algebraic Topology, Springer (Indian reprint) 2007.
2. J.R. Munkres. Topology, Prentice Hall of India (India reprint) 2007.

**MMT3121: THEORY OF SAMPLE SURVEY**

**Credits : 05**

**LTP 410**

**Course Description:**

The aim of this course is to cover sampling design and analysis methods that would be useful for research and management in many fields. A well-designed sampling procedure ensures to summarize and analyze data with a minimum of assumptions and complications.

**Course learning outcomes:** After completion of this course, students will be able to:

**CO1:** understand the principles underlying sampling as a means of making inferences about a population.

**CO2:** understand the difference between randomization theory and model-based analysis.

**CO3:** be able to analyse data from multi-stage surveys.

**Contents:**

**Section-A**

Concepts of population, population unit, sample, sample size, parameter, statistics estimator, biased and unbiased estimator, mean square error, standard error. Census and Sample surveys, Sampling and Non sampling errors, Concepts of Probability and non-probability sampling, sampling scheme and sampling strategy, Introduction of Simple Random Sampling (Use of Lottery Method, Random numbers and Pseudo random numbers).

**Section-B**

Simple Random sampling (with or without replacement); Estimation of population Mean and Total, Expectation and Variance of these Estimators, unbiased estimators of the variance of these Estimators.

**Section-C**

Estimation of Population proportion and Variance of these estimators, estimation of sample size based on desired accuracy, Confidence interval for population Mean and Proportion Concepts of Stratified population and stratified sample, estimation of population mean, and Total based on stratified sample.

**Section-D**

Expectation and variance of estimator of population mean and total assuming SRSWOR within strata. Unbiased estimator of the variances of these estimators. Proportional Allocation, Optimum allocation (Neyman allocation) with and without varying costs, Comparison of simple random sampling and stratified random sampling with proportional and optimum allocations.

**BOOKS RECOMMENDED:**

1. Sukhatme P.V., Sukkhatme P.V., Sukhatme S. & Ashok C. (1997): Sampling Theory of Surveys and Applications-Piyush Publications.

2. Des Raj and P.Chandok (1998): Sample Survey Theory. Narosa Publishing House.

3. Wiliam G. Cochran (1977): Sampling Techniques, 3rd Edition-John Wiely & Sons.

4. Parimal Mukhopadhyay (1988): Theory and Methods of Survey Sampling-Prentice Hall of India Pvt. Ltd.

5. Murthy M.N. (1977): Sampling Theory of Methods-Statistical Publishing Society, Culcutta.

**MMT3122: SPECIAL FUNCTIONS**

**Credits : 05**

**LTP 410**

**Course Description:**

The aim of this course is to determine properties of Bessel's functions of first and second kind, Legendre Polynomial and Hermite Polynomials which may be solved by application of special functions.

**Course learning outcomes:** After completion of this course, students will be able to:

CO1: understand special functions of various engineering problem and to know the application of some basic mathematical methods via all these special functions.

CO2: explain the applications and the usefulness of these special functions.

**Contents:**

**Section-A**

Bessel's functions of first and second kind, Recurrence relations, Generating functions, Trigonometric expansions, Asymptotic expansion, Neumann Expansion theory.

**Section-B**

Legendre's functions, Laplace integral for the Legendre Polynomials, Generating functions, Recurrence relations, Orthogonality, solution of Legendre's equations.

**Section-C**

Hermite Polynomials, Recurrence relations, Rodrigue formula. Hypergeometric function, solution of hypergeometric equation, Kummer function and it's asymptotic expansion.

**Section-D**

Barnes Contour Integral, Integral representation, Gauss Theorem, Kummer's theorem, Vander monde's theorem.

**BOOKS RECOMMENDED:**

1. Luke, Y.P.: The Special Functions and Their Approximation

2. Rainville, F.D.: Special Functions

3. Titchmarh, E.C.: The Theory of Functions.



**MMT3123: REPRESENTATION THEORY OF FINITE GROUPS**

**Credits : 05**

**LTP 410**

**Course Description:**

This course is aimed at fundamental concepts in abstract algebra and covers the representation theory of finite groups. Representation theory is an important topic in mathematics, as well as having applications in physics and chemistry.

**Course learning outcomes:** After completion of this course, students will be able to:

**CO1:** give an account of important concepts and definitions in representation theory for finite groups.

**CO2:** exemplify and interpret important concepts in specific cases.

**CO3:** use the theory, methods and techniques of the course to solve mathematical problems.

**Contents:**

**Section-A**

Semi-simple modules, semi-simple rings, Wedderburn Artin theorem, Maschke's theorem, Tensor products of modules and algebras.

**Section-B**

Examples of Decomposition of Group algebras, Simple Modules over K[G], Representations of Groups, K(G)-modules, K[G]-submodules and reducibility.

**Section-C**

Schur's lemma, Characters of representations, Orthogonality relations, The number of irreducible characters. Integrity of complex characters.

**Section-D**

Buruside's paqb-Theorem, Tensor product of representations, Induced representations, Restriction, and Induction, Frobenius reciprocity theorems.

**BOOKS RECOMMENDED:**

1. T.Y.Lam, A First Course in Non-commutative Rings, Graduate Texts in Mathematics; 131, Springer Verlag 1991.

2. C.Musili, Representation of Finite Groups, Hindustan Book Agency, 1993.

3. Gordon James and Martin Liebeck, Representation and Characters of Groups, Cambridge University Press, 1993.

**MMT3124: ANALYTIC NUMBER THEORY**

**Credits : 05**

**LTP 410**

**Course Description:** This course is aimed to illustrate how general methods of analysis can be used to obtain results about integers and prime numbers, to investigate the distribution of prime numbers and to consolidate earlier knowledge of analysis through applications.

**Course learning outcomes:** After completion of this course, students will be able to:

**CO1:** Understand better the distribution of prime numbers.

**CO2:** Know the basic theory of zeta –functions.

**CO3:** Understand the applications of Dirichlet's product.

**CO4:** understand the concept of Bell series.

**Contents:**

**Section-A**

Arithmetic Functions: Infinitude of primes, Euler zeta function, Arithmetic functions, The Mobius function, Euler totient, the Dirichlet product, Dirichlet inverses, Group structure on arithmetic functions, Multiple Dirichlet products, Group of arithmetic functions as a Q-vector space and its direct sum decomposition.

**Section-B**

The Mangoldt function, multiplicative functions and Dirichlet multiplication, completely multiplicative functions. The Bell Series: Generalized convolution, Bell series of arithmetic functions and Dirichlet multiplication, Derivatives of arithmetic functions.

**Section-C**

Averages of Arithmetic Functions: The Big-O notation, Euler's summation formula, the Riemann zeta function, asymptotic formulas for zeta functions, average order of some standard arithmetic functions, partial sums of Dirichlet product.

**Section-D**

The Riemann Zeta Function: The Hurwitz zeta function and its contour representation, the Hurwitz formula for ξ(s,a), the Riemann zeta function ξ(s,a) and its functional equations, Evaluation of ξ(-n,a), ξ(2), ξ(2k), Bernoulli numbers, Bernoulli polynomials and their properties, Power sums via Bernoulli numbers

**BOOKS RECOMMENDED:**

1. T. M. Apostol. *An introduction to analytic number theory.* Indian reprint, Springer (1976).

(Scope in Chapters 1-3, 12)

2. G. A. Jones and J. M. Jones. *Elementary number theory*. 6th Indian reprint, Springer (2011).

(Scope in Chapter 5-6, 8-9)

3. B. Berndt. *Ramanujan's Notebooks:* Part I. Springer, (1985)