MAR ATHANASIUS COLLEGE (AUTONOMOUS)
KOTHAMANGALAM, KERALA - 686666

NAAC Accredited 'A+' Grade Institution

Email: mac@macollege.in
www.macollege.in

SCHEME AND SYLLABUS

FOR

POST GRADUATE PROGRAMME UNDER CREDIT

AND SEMESTER SYSTEM

MAC-PG-CSS 2020

IN

MATHEMATICS

EFFECTIVE FROM ACADEMIC YEAR 2020-21

BOARD OF STUDIES IN MATHEMATICS (PG)

MAR ATHANASIUS COLLEGE (AUTONOMOUS)
KOTHAMANGALAM

Academic Council

COMPOSITION – With Effect From 01-06-2020

Chairperson : **Dr. Shanti.A.Avirah**
Principal
Mar Athanasius College (Autonomous), Kothamangalam

Experts/Academicians from outside the college representing such areas as Industry, Commerce, Law, Education, Medicine, Engineering, Sciences etc.

1. **Dr. Winny Varghese**
Secretary
Mar Athanasius College Association
Kothamangalam

2. **Prof. Dr. V.N. Rajasekharan Pillai**
Former Vice-Chairman
University Grants Commission,
New Delhi.

3. **Dr. R.K. Chauhan**
Former Vice-Chancellor, Lingaya's University,
Faridabad, Haryana -121002

4. **Dr. Sheela Ramachandran**
Pro-Chancellor,
Atmiya University
Rajkot.

5. **Prof. Kuruvilla Joseph**
Senior Professor and Dean,
Indian Institute of Space Science and Technology (IIST),
Department of Space, Govt. of India, Valiyamala, Thiruvananthapuarm

6. **Dr. M.C. Dileep Kumar**
Former Vice Chancellor
SreeSankaracharya Sanskrit University
Kalady, Kerala, India

7. **Dr. Mathew. K.**
Principal
Mar Athanasius College of Engineering,
Kothamangalam, Kerala - 686 666

8. **Adv. George Jacob**
Senior Advocate
High Court of Kerala
Ernakulam

Nominees of the university not less than Professors

9. **Dr. Biju Pushpan**
SAS SNDP Yogam College
Konni

10. **Dr. Suma Mary Scharia**
UC College
Aluva

11. **Dr. V.B. Nishi**
Associate Professor
Sree Shankara College, Kalady.

Member Secretary

12. **Dr. M.S.Vijayakumary**

Dean – Academics

Mar Athanasius College (Autonomous)

Kothamangalam

Four teachers of the college representing different categories of teaching staff by rotation on the basis of seniority of service in the college.

13. **Dr. Bino Sebastian. V** (Controller of Examinations)

14. **Dr. Manju Kurian,** Asst. Professor, Department of Chemistry

15. **Dr. Smitha Thankachan**, Asst. Professor, Department of Physics

16. **Dr. Asha Mathai**, Asst. Professor, Department of Malayalam

Heads of the Departments

17. **Dr. Jayamma Francis**, Head, Department of Chemistry
18. **Dr. Mini Varghese**, Head, Department of Hindi
19. **Ms. Shiny John**, Head, Department of Computer Science
20. **Dr. Igy George**, Head, Department of Economics
21. **Dr. Rajesh.K. Thumbakara**, Head, Department of Mathematics
22. **Dr. Aji Abraham**, Head, Department of Botany
23. **Dr. Selven S.**, Head, Department of Zoology
24. **Dr. Deepa. S**, Head, Department of Physics
25. **Dr. Aswathy Balachandran**, Head, Department of English
26. **Dr. Diana Ann Issac**, Head, Department of Commerce
27. **Ms. Seena John**, Head, Department of Malayalam
28. **Ms. Diana Mathews**, Head, Department of Sociology
29. **Ms. Sudha. V**, Head, Department of Statistics
30. **Dr. Jani Chungath**, Head, Department of History
31. **Sri. Haary Benny Chettiamkudiyil**, Head, Department of Physical Education
32. **Ms. Shari Sadasivan**, Head, Department of Marketing and International Business
33. **Dr. Julie Jacob**, Head, Department of Biochemistry
34. **Ms. Nivya Mariyam Paul**, Head, Department of Microbiology
35. **Ms. Jaya Vinny Eappen**, Head, Department of Biotechnology
36. **Ms. Shalini Binu**, Head, Department of Actuarial Science
37. **Ms. Simi. C.V**, Head, Post Graduate Department of History
38. **Ms. Sari Thomas**, Head, Post Graduate Department of Statistics
39. **Ms. Sheeba Stephen**, Head, Department of B.Com Model III - Tax Procedure and Practice
40. **Ms. Dilmol Varghese** , Head, Post Graduate Department of Zoology
41. **Ms. Bibin Paul**, Head, Post Graduate Department of Sociology

BOARD OF STUDIES IN MATHEMATICS (PG)	
NAME	DESIGNATION
CHAIRPERSON	
Dr. Rajesh K. Thumbakara	Assistant Professor and Head, Department of Mathematics
EXPERTS (2)	
Dr. B. Kannan	Professor, Department of Computer Application, Cochin University of Science and Technology Kochi
Dr. Arun K. R.	Assistant Professor, Department of Mathematics, Indian Institute of Science Education and Research(IISER), Thiruvananthapuram.
ONE EXPERT TO BE NOMINATED BY THE VICE CHANCELLOR (MGU)	
Dr. Antony Mathews	Associate Professor, Department of Mathematics, S.B College, Changanassery.
MEMBER TEACHERS IN THE DEPARTMENT	
Mercy Varghese	Associate Professor, Department of Mathematics
Dr. Latha S. Nair	Assistant Professor, Department of Mathematics
Dr. Bino Sebastian V.	Assistant Professor, Department of Mathematics
Dr. Susan Ray Joseph	Assistant Professor, Department of Mathematics
Dr. Mary Elizabeth Antony	Assistant Professor, Department of Mathematics
MEMBER FROM INDUSTRY	
Sri. C. J. George	Managing Director, BNP Paribas, Geojith
MERITORIOUS ALUMNUS	
Tintu Chacko	Scientist/Engineer ‘SD’, ISRO, Bangalore

LIST OF POST GRADUATE PROGRAMMES IN MAR ATHANASIUS COLLEGE (AUTONOMOUS), KOTHAMANGALAM

SL. NO.	PROGRAMME	DEGREE	FACULTY
1	ENGLISH	MA	LANGUAGE AND LITERATURE
2	ECONOMICS	MA	SOCIAL SCIENCES
3	SOCIOLOGY	MA	SOCIAL SCIENCES
4	HISTORY	MA	SOCIAL SCIENCES
5	MATHEMATICS	M.Sc	SCIENCE
6	CHEMISTRY	M.Sc	SCIENCE
7	PHYSICS	M.Sc	SCIENCE
8	BOTANY	M.Sc	SCIENCE
9	STATISTICS	M.Sc	SCIENCE
10	ZOOLOGY	M.Sc	SCIENCE
11	BIOCHEMISTRY	M.Sc	SCIENCE
12	BIOTECHNOLOGY	M.Sc	SCIENCE
13	MICROBIOLOGY	M.Sc	SCIENCE
14	ACTUARIAL SCIENCE	M.Sc	SCIENCE
15	COMMERCE (SPECIALISATION - FINANCE AND TAXATION)	M.Com	COMMERCE
16	COMMERCE (SPECIALISATION - MARKETING AND INTERNATIONAL BUSINESS)	M.Com	COMMERCE

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Preface

Mathematics is central to science and society embedded in every discipline and is the essential tool to empower people with the knowledge, competencies and attitudes which are precursors for this dynamic world to compete in the context of globalization. The curriculum and syllabi of any academic programme has to be systematically subjected to thorough revision so as to make them more relevant and meaningful.

The Board of studies in mathematics proceeded with this task of restructuring the PG programme in Mathematics in Mar Athanasius College (Autonomous) as per the terms of reference and guidelines given by the university in line with the proposals put forward by the University Grants Commission. The board of studies prepared a comprehensive plan of action for introducing the outcome based CSS in the PG programmes from the academic year 2020-21 based on the syllabus approved by Mahatma Gandhi University for the academic year 2019-20. The revisions were effected based on the recommendations made by the board of studies (PG). It is envisaged that students will have the maximum opportunity to pursue their own interest and chosen fields of courses. The diversity available within the overall frame work helps flexible specialization.

We gratefully acknowledge the assistance and guidance received from the management, principal and the university and all those who have contributed in different ways in the venture.

It is recommended that the content of the syllabus be reviewed and adopted in the consultative process, made use of in future curriculum initiatives and also in the periodical revision of syllabus and curriculum.

I hope this restructured syllabus and curriculum would enrich and equip the students to meet future challenges.

Dr. Rajesh K. Thumbakara
Chairman
Board of Studies (PG Mathematics)

REGULATIONS OF THE POSTGRADUATE PROGRAMMES
UNDER CREDIT SEMESTER SYSTEM
MAC-PG-CSS 2020
(2020 Admission onwards)

1. SHORT TITLE

1.1 These Regulations shall be called **“Mar Athanasius College (Autonomous) Regulations (2020) governing Postgraduate Programmes under the Credit Semester System (MAC-PG-CSS2020)”.**

1.2 These Regulations shall come into force from the Academic Year 2020-2021.

2. SCOPE

2.1 The regulations provided herein shall apply to all Regular Postgraduate (PG) Programmes, M.A. /M.Sc. /M.Com. conducted by Mar Athanasius College (Autonomous) with effect from the academic year 2020-2021 admission onwards.

3. DEFINITIONS

3.1 **‘Academic Committee’** means the Committee constituted by the Principal under this regulation to monitor the running of the Post-Graduate programmes under the Credit Semester System (MAC-PG-CSS2020).

3.2 **‘Academic Week’** is a unit of five working days in which distribution of work is organized from day one to day five, with five contact hours of one hour duration on each day. A sequence of 18 such academic weeks constitutes a semester.

3.3 ‘**Audit Course**’ is a course for which no credits are awarded.

3.4 **‘CE’ means Continuous Evaluation (Internal Evaluation)**

3.5 **‘College Co-ordinator’** means a teacher from the college nominated by the Principal to look into the matters relating to MAC-PG-CSS2020 for programmes conducted in the College.

3.6 **‘Comprehensive Viva-Voce’** means the oral examinations conducted by the appointed examiners and shall cover all courses of study undergone by a student for the programme.

3.7 **‘Common Course’** is a core course which is included in more than one programme with the same course code.

3.8 ‘**Core Course**’ means a course that the student admitted to a particular programme must successfully complete to receive the Degree and which cannot be substituted by any other course.

3.9 ‘**Course**’ means a segment of subject matter to be covered in a semester. Each Course is to be designed variously under lectures / tutorials / laboratory or fieldwork/seminar/ project/practical training / assignments/evaluation etc., to meet effective teaching and learning needs.

3.10 **‘Course Code’** means a unique alpha numeric code assigned to each course of a programme.

3.11 ‘**Course Credit**’ One credit of the course is defined as a minimum of one hour lecture /minimum of 2 hours lab/field work per week for 18 weeks in a Semester. The course will be considered as completed only by conducting the final examination.

3.12 **‘Course Teacher’** means the teacher of the institution in charge of the course offered in the programme.

3.13 **‘Credit (Cr)’** of a course is a numerical value which depicts the measure of the weekly unit of work assigned for that course in a semester.

3.14 ‘**Credit Point(CP)**’ of a course is the value obtained by multiplying the grade point (GP) by the Credit (Cr) of the course **CP=GP x Cr**.

3.15 ‘**Cumulative Grade Point Average(CGPA)**’ is the value obtained by dividing the sum of credit points in all the courses taken by the student for the entire programme by the total number of credits and shall be rounded off to two decimal places. CGPA determines the overall performance of a student at the end of a programme.

(CGPA = Total CP obtained/ Total credits of the programme)

3.16 ‘**Department**’ means any teaching Department offering a programme of study in the institution.

3.17 ‘**Department Council**’ means the body of all teachers of a Department in a College.

3.18 **‘Dissertation’** means a long document on a particular subject in connection with the project /research/ field work etc.

3.19 ‘**Duration of Programme**’ means the period of time required for the conduct of the programme. The duration of post-graduate programme shall be 4 semesters spread over two academic years.

3.20 ‘**Elective Course**’ means a course, which can be substituted, by equivalent course from the same subject.

3.21 **‘Elective Group’** means a group consisting of elective courses for the programme.

3.22 **‘ESE’ means End Semester Evaluation (External Evaluation).**

3.23 **‘Evaluation’** is the process by which the knowledge acquired by the student is quantified as per the criteria detailed in these regulations.

3.24 **External Examiner** is the teacher appointed from other colleges for the valuation of courses of study undergone by the student in a college. The external examiner shall be appointed by the college.

3.25 ‘**Faculty Advisor**’ is a teacher nominated by a Department Council to coordinate the continuous evaluation and other academic activities undertaken in the Department.

3.26 ‘**Grace Grade Points**’ means grade points awarded to course(s), recognition of the students' meritorious achievements in NSS/ Sports/ Arts and cultural activities etc.

3.27 ‘**Grade Point**’ (GP) Each letter grade is assigned a Grade point (GP) which is an integer indicating the numerical equivalent of the broad level of performance of a student in a course.

3.28 '**Grade Point Average(GPA)**' is an index of the performance of a student in a course. It is obtained by dividing the sum of the weighted grade point obtained in the course by the sum of the weights of Course.**(GPA= $\sum$WGP / $\sum$W)**

3.29 '**Improvement Course**' is a course registered by a student for improving his performance in that particular course.

3.30 **'Internal Examiner'** is a teacher nominated by the department concerned to conduct internal evaluation.

3.31 '**Letter Grade**' or '**Grade**' for a course is a letter symbol (A+, A, B+, B, C+, C, D) which indicates the broad level of performance of a student for a course.

3.32 **MAC-PG-CSS2020 means Mar Athanasius College Regulations Governing Post Graduate programmes under Credit Semester System, 2020.**

3.33 '**Parent Department**' means the Department which offers a particular postgraduate programme.

3.34 '**Plagiarism**' is the unreferenced use of other authors' material in dissertations and is a serious academic offence.

3.35 '**Programme**' means the entire course of study and Examinations.

3.36 **'Project'** is a core course in a programme. It means a regular project work with stated credits on which the student undergo a project under the supervision of a teacher in the parent department/ any appropriate research centre in order to submit a dissertation on the project work as specified. It allows students to work more autonomously to construct their own learning and culminates in realistic, student-generated products or findings.

3.37 '**Repeat Course**' is a course to complete the programme in an earlier registration.

3.38 '**Semester**' means a term consisting of a minimum of 90 working days, inclusive of examination, distributed over a minimum of 18 weeks of 5 working days each.

3.39 '**Seminar**' means a lecture given by the student on a selected topic and expected to train the student in self-study, collection of relevant matter from various resources, editing, document writing and presentation.

3.40 '**Semester Grade Point Average(SGPA)**' is the value obtained by dividing the sum of credit points (CP) obtained by the student in the various courses taken in a semester by the total number of credits for the course in that semester. The SGPA shall be rounded off to two decimal places. SGPA determines the overall performance of a student at the end of a semester (SGPA = Total CP obtained in the semester / Total Credits for the semester).

3.41 '**Tutorial**' means a class to provide an opportunity to interact with students at their individual level to identify the strength and weakness of individual students.

3.42 '**Weight**' is a numeric measure assigned to the assessment units of various components of a course of study.

3.43 **University** means Mahatma Gandhi University Kottayam to which the college is affiliated.

3.44 '**Weighted Grade Point (WGP)**' is grade points multiplied by weight. **(WGP = GP x W)**

3.45 **'Weighted Grade Point Average (WGPA)' is an index of the performance of a student in a course. It is obtained by dividing the sum of the weighted grade points by the sum of the weights. WGPA shall be obtained for CE (Continuous Evaluation) and ESE (End Semester Evaluation) separately and then the combined WGPA shall be obtained for each course.**

4. ACADEMIC COMMITTEE

4.1. There shall be an Academic Committee constituted by the Principal to Manage and monitor the working of MAC-PG-CSS 2020.

4.2. The Committee consists of:

1. Principal
2. Dean, Administration
3. Dean, Academics

4. IQAC Coordinator
5. Controller of Examinations
6. One Faculty each representing Arts, Science, Commerce, Languages, and Self Financing Programmes

5. PROGRAMME STRUCTURE

5.1 Students shall be admitted to post graduate programme under the various Faculties. The programme shall include three types of courses, Core Courses, Elective Courses and Common core courses. There shall be a project with dissertation and comprehensive viva-voce as core courses for all programmes. The programme shall also include assignments / seminars/ practical's etc.

5.2 No regular student shall register for more than 25 credits and less than16 credits per semester unless otherwise specified. The total minimum credits, required for completing a PG programme is 80.

5.3. Elective Courses and Groups

5.3.1 There shall be various groups of Programme Elective courses for a Programme such as Group A, Group B etc. for the choice of students subject to the availability of facility and infrastructure in the institution and the selected group shall be the subject of specialization of the programme.

5.3.2 The elective courses shall be either in fourth semester or distributed among third and fourth semesters. There may be various groups of Elective courses (three elective courses in each group) for a programme such as Group A, Group B etc. for the choice of students, subject to the availability of facility and infrastructure in the institution.

5.3.3 The selection of courses from different elective groups is not permitted.

5.3.4 The elective groups selected for the various Programmes shall be intimated to the Controller of Examinations within two weeks of commencement of the semester in which the elective courses are offered. The elective group selected for the students who are admitted in a particular academic year for various programmes shall not be changed.

5.4 Project Work

5.4.1. Project work shall be completed in accordance with the guidelines given in the curriculum.

5.4.2 Project work shall be carried out under the supervision of a teacher of the department concerned.

5.4.3. A candidate may, however, in certain cases be permitted to work on the project in an Industrial/Research Organization on the recommendation of the supervising teacher.

5.4.4 There shall be an internal assessment and external assessment for the project work.

5.4.5. The Project work shall be evaluated based on the presentation of the project work done by the student, the dissertation submitted and the viva-voce on the project.

5.4.6 The external evaluation of project work shall be conducted by two external examiners from different colleges and an internal examiner from the college concerned.

5.4.7 The final Grade of the project (External) shall be calculated by taking the average of the Weighted Grade Points given by the two external examiners and the internal examiner.

5.5 **Assignments:** Every student shall submit at least one assignment as an internal component for each course.

5.6 **Seminar Lecture:** Every PG student shall deliver one seminar lecture as an Internal component for every course with a weightage of two. The seminar lecture is expected to train the student in self-study, collection of relevant matter from the various resources, editing, document writing and presentation.

5.7 **Test Papers (Internal):** Every PG student shall undergo at least two class tests as an internal component for every course with a weight one each. The best two shall be taken for awarding the grade for class tests.

5.8. **No courses shall have more than 5 credits unless otherwise specified.**

5.9. **Comprehensive Viva-Voce** -Comprehensive Viva-Voce shall be conducted at the end of fourth semester of the programme and its evaluation shall be conducted by the examiners of the project evaluation.

5.9.1. Comprehensive Viva-Voce shall cover questions from all courses in the Programme.

5.9.2. There shall be an internal assessment and an external assessment for the Comprehensive Viva-Voce.

6. ATTENDANCE

6.1. The minimum requirement of aggregate attendance during a semester for appearing at the end-semester examination shall be 75%. Condonation of shortage of attendance to a maximum of 15 days in a semester subject to a maximum of two times during the whole period of the programme may be granted by the University.

6.2 If a student represents his/her institution, University, State or Nation in Sports, NCC, or Cultural or any other officially sponsored activities such as college union/ university union etc., he/she shall be eligible to claim the attendance for the actual number of days participated subject to a maximum 15 days in a Semester based on the specific recommendations of the Head of the Department or teacher concerned.

6.3 Those who could not register for the examination of a particular semester due to shortage of attendance may repeat the semester along with junior batches, without considering sanctioned strength, subject to the existing University Rules and Clause 7.2.

6.4. A Regular student who has undergone a programme of study under earlier regulation/ Scheme and could not complete the Programme due to shortage of attendance may repeat the semester along with the regular batch subject to the condition that he has to undergo all the examinations of the previous semesters as per the MAC-PG-CSS2020 regulations and conditions specified in 6.3.

6.5 A student who had sufficient attendance and could not register for fourth semester examination can appear for the end semester examination in the subsequent years with the attendance and progress report from the principal.

7. REGISTRATION/ DURATION

7.1 A student shall be permitted to register for the programme at the time of admission.

7.2 A student who registered for the Programme shall complete the Programme within a period of four years from the date of commencement of the programme.

7.3 Students are eligible to pursue studies for additional post graduate degree. They shall be eligible for award of degree only after successful completion of two years (four semesters of study) of college going.

8. ADMISSION

8.1 The admission to all PG programmes shall be done through the Centralised Allotment Process of Mar Athanasius College (Autonomous), Kothamangalam (MAC-PG CAP) as per the rules and regulations prescribed by the affiliating university and the Government of Kerala from time to time.

8.2 The eligibility criteria for admission shall be as announced by the Parent University from time to time.

9. ADMISSION REQUIREMENTS

9.1 Candidates for admission to the first semester of the PG programme through CSS shall be required to have passed an appropriate Degree Examination of Mahatma Gandhi University as specified or any other examination of any recognized University or authority accepted by the Academic council of Mahatma Gandhi University as eligible thereto.

9.2 Students admitted under this programme are governed by the Regulations in force.

10. PROMOTION:

10.1 A student who registers for the end semester examination shall be promoted to the next semester.

10.2 A student having 75% attendance and who fails to register for examination of a particular semester will be allowed to register notionally and is promoted to the next semester, provided application for notional registration shall be submitted within 15 days from the commencement of the next semester.

10.3 The medium of Instruction shall be English except programmes under faculty of Language and Literature.

11. EXAMINATIONS

11.1 **End-Semester Examinations**: The examinations shall be at the end of each Semester of three hour duration for each centralised and practical course.

11.2 Practical examinations shall be conducted at the end of each semester or at the end of even semesters as prescribed in the syllabus of the particular programme. The number of examiners for the practical examinations shall be prescribed by the Board of Studies of the programmes.

11.3 A question paper may contain short answer type/annotation, short essay type questions/problems and long essay type questions. Different types of questions shall have different weightage.

12. EVALUATION AND GRADING

12.1 **Evaluation:** The evaluation scheme for each course shall contain two parts; (a) End Semester Evaluation (ESE) (External Evaluation) and (b) Continuous Evaluation (CE) (Internal Evaluation). 25% weightage shall be given to internal evaluation and the remaining 75% to external evaluation and the ratio and weightage between internal and external is 1:3. Both End Semester Evaluation (ESE) and Continuous Evaluation(CE) shall be carried out using direct grading system.

12.2 **Direct Grading: The direct grading for CE (Internal) and ESE (External Evaluation) shall be based on 6 letter grades (A+, A, B, C, D and E) with numerical values of 5, 4, 3, 2, 1 and 0 respectively.**

12.3 **Grade Point Average (GPA): Internal and External components are separately graded and the combined grade point with weightage 1 for internal and 3 for external shall be applied to calculate the Grade Point Average (GPA) of each course. Letter grade shall be assigned to each course based on the categorization provided in 12.16.**

12.4 **Internal evaluation:** The internal evaluation shall be based on predetermined transparent system periodic written tests, assignments, seminars, lab skills, records, viva-voce etc.

12.5 Components of internal (CE) and External Evaluation (ESE): Grades shall be given to the evaluation of theory / practical / project / comprehensive viva-voce and all internal evaluations are based on the Direct Grading System.

Proper guidelines shall be prepared by the BOS for evaluating the assignment, seminar, practical, project and comprehensive viva-voce within the framework of the regulation.

12.6 There shall be no separate minimum grade point for internal evaluation.

12.7 **The model of the components and its weightages for Continuous Evaluation (CE) and End Semester Evaluation (ESE) are shown in below:**

a) For Theory (CE) (Internal)

	Components	Weightage
i.	Assignment	1
ii.	Seminar	2
iii.	Best Two Test papers	2 (1 each)
Total		**5**

(Average grade of the best two papers can be considered. For test paper all the Questions shall be set in such a way that the answers can be awarded A+, A, B, C, D, E grades)

b) For Theory (ESE) (External)

Evaluation is based on the pattern of Question specified **in 12.15.5**

c) For Practical (CE) (Internal)

Components	Weightage
Written / Lab Test	2
Lab Involvement and Record	1
Viva	2
Total	**5**

(The components and weightage of the practical (Internal) can be modified by the concerned BOS without changing the total weightage 5)

d) For Practical (ESE) (External)

Components	Weightage
Written / Lab Test	7
Lab Involvement and Record	3
Viva	5
Total	**15**

(The components and weightage of the practical (External) can be modified by the concerned BOS without changing the total weightage 15)

e) For Project (CE) (Internal)

Components	**Weightage**
Relevance of the topic and analysis	2
Project content and presentation	2
Project viva	1
Total	**5**

(The components and the weightage of the components of the Project (Internal) can be modified by the concerned BOS without changing the total weightage 5)

f) For Project (ESE) (External)

Components	**Weightage**
Relevance of the topic and analysis	3
Project content and presentation	7
Project viva	5
Total	**15**

(The components and the weightage of the components of the Project (External) can be modified by the concerned BOS without changing the total weightage 15)

g) Comprehensive viva-voce (CE) (Internal)

Components	**Weightage**
Comprehensive viva-voce(all courses from first semester to fourth semester)	5
Total	**5**

(Weightage of the components of the Comprehensive viva-voce(Internal) shall not be modified.)

h)Comprehensive viva-voce (ESE) (External)

Components	Weightage
Comprehensive viva-voce(all courses from first semester to fourth semester)	15
Total	**15**

(Weightage of the components of the Comprehensive viva-voce (External) shall not be modified.)

12.8 **All grade point averages shall be rounded to two digits.**

12.9 To ensure transparency of the evaluation process, the internal assessment grade awarded to the students in each course in a semester shall be published on the notice board at least one week before the commencement of external examination.

12.10 **There shall not be any chance for improvement for Internal Grade.**

12.11 The course teacher and the faculty advisor shall maintain the academic record of each student registered for the course and a copy should be kept in the college for verification for at least two years after the student completes the programme.

12.12 **External Evaluation.** The external examination in theory courses is to be conducted by the College at the end of the semester. The answers may be written in English or Malayalam except those for the Faculty of Languages. The evaluation of the answer scripts shall be done by examiners based on a well-defined scheme of valuation. The external evaluation shall be done immediately after the examination.

12.13 Photocopies of the answer scripts of the external examination shall be made available to the students on request as per the rules prevailing in the University.

12.14 The question paper should be strictly on the basis of model question paper set and directions prescribed by the BOS.

12.15. **Pattern of Questions**

12.15.1 **Questions shall be set to assess knowledge acquired, standard, and application of knowledge, application of knowledge in new situations, critical evaluation of knowledge and the ability to**

synthesize knowledge. Due weightage shall be given to each module based on content/teaching hours allotted to each module.

12.15.2 The question setter shall ensure that questions covering all skills are set.

12.15.3 A question paper shall be a judicious mix of short answer type, short essay type /problem solving type and long essay type questions.

12.15.4 The question shall be prepared in such a way that the answers can be awarded A+, A, B, C, D, E grades.

12.15.5 Weight: Different types of questions shall be given different weights to quantify their range as follows:

Sl.No.	Type of Questions	Weight	Number of questions to be answered
1	Short Answer type questions	1	8 out of 10
2	Short essay / problem solving type questions	2	6 out of 8
3	Long Essay Type questions	5	2 out of 4

12.16. **Pattern of question for practical**. The pattern of questions for external evaluation of practical shall be prescribed by the Board of Studies.

12.17. **Direct Grading System**

Direct Grading System based on a 6-point scale is used to evaluate the Internal and External examinations taken by the students for various courses of study.

Grade	Grade point(G)	Grade Range
A+	5	4.50 to 5.00
A	4	4.00 to 4.49
B	3	3.00 to 3.99
C	2	2.00 to 2.99
D	1	0.01 to 1.99
E	0	0.00

12.18. **Performance Grading**

Students are graded based on their performance (GPA/SGPA/CGPA) at the examination on a 7-point scale as detailed below.

Range	Grade	Indicator
4.50 to 5.00	**A+**	**Outstanding**
4.00 to 4.49	**A**	**Excellent**
3.50 to 3.99	**B+**	**Very good**
3.00 to 3.49	**B**	**Good(Average)**
2.50 to 2.99	**C+**	**Fair**
2.00 to 2.49	**C**	**Marginal**
up to 1.99	**D**	**Deficient(Fail)**

12.19 **No separate minimum is required for Internal Evaluation for a pass, but a minimum grade is required for a pass in an External Evaluation.**

However, a minimum C grade is required for pass in a Course

12.20 A student who fails to secure a minimum grade for a pass in a course will be permitted to write the examination along with the next batch.

12.21 **Improvement of Course**- The candidate who wish to improve the grade/grade point of the external examination of the of a course/ courses he/ she has passed can do the same by appearing in the external examination of the semester concerned along with the immediate junior batch. This facility is restricted to first and second semester of the programme.

12.22 **One Time Betterment Programme**- A candidate will be permitted to improve the **CGPA** of the programme within a continuous period of four semesters immediately following the completion of the programme allowing only once for a particular semester. The **CGPA** for the betterment appearance will be computed based on the **SGPA** secured in the original or betterment appearance of each semester whichever is higher.

If a candidate opts for the betterment of **CGPA** of a programme, he/she has to appear for the external examination of the entire semester(s) excluding practical /project/comprehensive viva-voce. One time betterment programme is restricted to students who have passed in all courses of the programme at the regular (First appearance)

12.23 **Semester Grade Point Average(SGPA) and Cumulative Grade Point Average (CGPA) Calculations.** The SGPA is the ratio of sum of the credit point of all courses taken by a student in a semester to the total credit for that semester. After the successful completion of a semester, Semester Grade Point

Average(SGPA) of a student in that semester is calculated using the formula given below.

Semester Grade Point Average -SGPA (S_j) = $\sum(C_i \times G_i) / \sum C_i$

(SGPA= Total credit Points awarded in a semester / Total credits of the semester)

Where 'S_j' is the j^{th} semester, 'G_i' is the grade point scored by the student in the i^{th} course 'C_i' is the credit of the i^{th} course.

12.24 **Cumulative Grade Point Average** (**CGPA**) of a programme is calculated using the formula:-

Cumulative Grade Point Average (CGPA) = $\sum(C_i \times S_i) / \sum C_i$

(CGPA= Total credit Points awarded in all semester / Total credits of the programme)

Where 'C_i' is the credit for the i^{th} semester, 'S_i' is the SGPA for the i^{th} semester. The **SGPA** and **CGPA** shall be rounded off to 2 decimal points.

For the successful completion of semester, a student shall pass all courses and score a minimum **SGPA** of 2.0. However a student is permitted to move to the next semester irrespective of her/his **SGPA**

13. GRADE CARD

13.1 The Institution under its seal shall issue to the students, a consolidated grade card on completion of the programme, which shall contain the following information.

a) Name of the University.

b) Name of college

c) Title of the PG Programme.

d) Name of Semesters

e) Name and Register Number of students

f) Code, Title, Credits and Max GPA (Internal, External & Total) of each course (theory &practical), project, viva etc in each semester.

g) Internal, external and Total grade, Grade Point (G), Letter grade and Credit point (P) in each course opted in the semester.

h) The total credits and total credit points in each semester.

i) Semester Grade Point Average (SGPA) and corresponding Grade in each semester

j) Cumulative Grade Point Average (CGPA), Grade for the entire programme.

k) Separate Grade card will be issued.

l) Details of description of evaluation process- Grade and Grade Point as well as indicators, calculation methodology of SGPA and CGPA as well as conversion scale shall be shown on the reverse side of the grade card.

14. AWARD OF DEGREE - The successful completion of all the courses with 'C' grade within the stipulated period shall be the minimum requirement for the award of the degree.

15. MONITORING COMMITTEE

There shall be a Monitoring Committee constituted by the Principal to monitor the internal evaluations conducted.

16. RANK CERTIFICATE

Rank certificate shall be issued to candidates who secure positions 1st and 2nd. Candidates shall be ranked in the order of merit based on the CGPA secured by them. Grace grade points awarded to the students shall not be counted for fixing the rank. Rank certificate shall be signed by the Principal and the Controller of Examinations.

17. GRIEVANCE REDRESSAL COMMITTEE

17.1 Department level: The College shall form a Grievance Redressal Committee in each Department comprising of the course teacher and one senior teacher as members and the Head of the Department as Chairperson. The Committee shall address all grievances relating to the internal assessment grades of the students.

17.2. College level: There shall be a college level Grievance Redressal Committee comprising of faculty advisor, college co-ordinator, one senior teacher and one staff council member and the Principal as Chairperson.

18. **FACTORY VISIT / FIELD WORK/VISIT:** Factory visit / field work/visit to a reputed research institute/ student interaction with renowned academicians

may be conducted for all Programmes before the commencement of Semester III.

19. **INTERNSHIP/ON THE JOB TRAINING:** Each student may undertake internship/on the job training for a period of not less than 15 days. The time, duration and structure of internship/on the job training can be modified by the concerned Board of Studies.

20. **TRANSITORY PROVISION**

Notwithstanding anything contained in these regulations, the Principal shall, for a period of three year from the date of coming into force of these regulations, have the power to provide by order that these regulations shall be applied to any programme with such modifications as may be necessary.

21. **REPEAL**

The Regulations now in force in so far as they are applicable to programmes offered by the college and to the extent they are inconsistent with these regulations are hereby repealed. In the case of any inconsistency between the existing regulations and these regulations relating to the Credit Semester System in their application to any course offered in a College, the latter shall prevail.

22. **Credits allotted for Programmes and Courses**

22.1 Total credit for each programme shall be **80**.

22.2 Semester-wise total credit can vary from 16 to 25

22.3 The minimum credit of a course is 2 and maximum credit is 5

23. **Common Course:** If a course is included as a common course in more than one programme, its credit shall be same for all programmes.

24. **Course Codes:** The course codes assigned for all courses (Core Courses, Elective Courses, Common Courses etc.) shall be unique.

25. **Models of distribution of courses, course codes, type of the course, credits, teaching hours for the M Sc Mathematics programme are given in the following table.**

M.Sc Mathematics
(Programme without practical)

Total Credits 80-Scheme of the syllabus

Semester	Course-code	Course name	Type of the course	Teaching Hours per week	Credit	Total Credits
I	PG20MT101	Linear Algebra	Core	5	4	20
	PG20MT102	Abstract Algebra	Core	5	4	
	PG20MT103	Real Analysis	Core	5	4	
	PG20MT104	Graph Theory	Core	5	4	
	PG20MT105	Basic Topology	Core	5	4	
II	PG20MT206	Complex Analysis	Core	5	4	20
	PG20MT207	Advanced Topology	Core	5	4	
	PG20MT208	Theory of Ordinary Differential Equations	Core	5	4	
	PG20MT209	Multivariable Calculus	Core	5	4	
	PG20MT210	Number Theory and Cryptography	Core	5	4	
III	PG20MT311	Measure Theory and Integration	Core	5	4	20
	PG20MT312	Functional Analysis	Core	5	4	
	PG20MT313	Differential Geometry	Core	5	4	
	PG20MT314	Partial Differential Equation	Core	5	4	
	PG20MT315	Optimization Techniques	Core	5	4	
IV	PG20MT416	Spectral Theory	Core	5	4	20
	PG20MT417	Operations Research	Core	5	4	
	Course.code18	Elective 1	Core Elective	5	3	
	Course.code19	Elective 2	Core Elective	5	3	
	Course.code20	Elective 3	Core Elective	5	3	
	Project-Course.code20		core	-	1	
	Comprehensive viva-voce Course.code21		core	-	2	
Total						**80**

Appendix

1. **Evaluation first stage – Both internal and external to be done by the teacher)**

Grade	Grade Points	Range
A+	5	4.50 to 5.00
A	4	4.00 to 4.49
B	3	3.00 to 3.99
C	2	2.00 to 2.99
D	1	0.01 to 1.99
E	0	0.00

The final Grade range for courses, SGPA and CGPA

Range	Grade	Indicator
4.50 to 5.00	A+	Outstanding
4.00 to 4.49	A	Excellent
3.50 to 3.99	B+	Very good
3.00 to 3.49	B	Good
2.50 to 2.99	C+	Fair
2.00 to 2.49	C	Marginal
Upto1.99	D	Deficient(Fail)

Theory-External-ESE

Maximum weight for external evaluation is 30. Therefore Maximum Weighted Grade Point (WGP) is 150

Type of Question	Qn. No.'s	Grade Awarded	Grade Point	Weights	Weighted Grade Point
Short Answer	1	A+	5	1	5
	2	-	-	-	-
	3	A	4	1	4
	4	C	2	1	2
	5	A	4	1	4
	6	A	4	1	4
	7	B	3	1	3
	8	A	4	1	4
	9	B	3	1	3
	10	-	-	-	
Short Essay	11	B	3	2	6
	12	A+	5	2	10
	13	A	4	2	8
	14	A+	5	2	10
	15	-	-	-	-
	16	-	-	-	-
	17	A	4	2	8
	18	B	3	2	6
Long Essay	19	A+	5	5	25
	20	-	-	-	-
	21	-	-	-	-
	22	B	3	5	15
			TOTAL	**30**	**117**

Calculation :
Overall Grade of the theory paper = Sum of Weighted Grade Points /Total Weight = 117/30 = 3.90 = Grade B

Theory-Internal-CE

Maximum weight for internal evaluation is 5. Therefore Maximum Weighted Grade Point (WGP) is 25.

Components	Weight (W)	Grade Awarded	Grade Point(GP)	WGP=W *GP	Overall Grade of the Course
Assignment	1	A	4	4	**WGP/Total Weight= 24/5 =4.8**
Seminar	2	A+	5	10	
Test Paper 1	1	A+	5	5	
Test Paper 2	1	A+	5	5	
Total	**5**			**24**	**A+**

Practical-External-ESE

Maximum weight for external evaluation is 15. Therefore Maximum Weighted Grade Point (WGP) is 75

Components	Weight(W)	Grade Awarded	Grade Point(GP)	WGP=W*GP	Overall Grade of the Course
Written/Lab Test	7	A	4	28	**WGP/Total Weight= 58 / 15 = 3.86**
Lab involvement & record	3	A+	5	15	
Viva	5	B	3	15	
Total	**15**			**58**	**B**

Practical-Internal-CE

Maximum weight for internal evaluation is 5. Therefore Maximum Weighted Grade Point (WGP) is 25

Components	Weight (W)	Grade Awarded	Grade Point(GP)	WGP=W *GP	Overall Grade of the Course
Written/ Lab Test	2	A	4	8	**WGP/Total Weight=17/5 =3.40**
Lab involvement & record	1	A+	5	5	
Viva	2	C	2	4	
Total	**5**			**17**	**B**

Project-External-ESE

Maximum weight for external evaluation is 15. Therefore Maximum Weighted Grade Point (WGP) is 75

Components	Weight (W)	Grade Awarded	Grade Point(GP)	WGP= W*GP	Overall Grade of the Course
Relevance of the topic & Analysis	3	C	2	6	**WGP/Total Weight = 56/15= 3.73**
Project Content &Presentation	7	A+	5	35	
Project Viva- Voce	5	B	3	15	
Total	**15**			**56**	**B**

Project - Internal-CE
Maximum weight for internal evaluation is 5. Therefore Maximum Weighted Grade Point (WGP) is 25

Components	Weight (W)	Grade Awarded	Grade Point(GP)	WGP=W *GP	Overall Grade of the Course
Relevance of the topic & Analysis	2	B	3	6	**WGP/Total Weight= 21/5 = 4.2**
Project Content & Presentation	2	A+	5	10	
Project Viva-Voce	1	A+	5	5	
Total	**5**			**21**	**A**

Comprehensive viva-voce-External-ESE
Maximum weight for external evaluation is 15. Therefore Maximum Weighted Grade Point (WGP) is 75

Components	Weight (W)	Grade Awarded	Grade Point(GP)	WGP=W*GP	Overall Grade of the Course
Comprehensive viva-voce	15	A	4	60	**WGP/Total Weight = 60 / 15 = 4**
Total	**15**			**60**	**A**

Comprehensive viva-voce-Internal-CE
Maximum weight for internal evaluation is 5. Therefore Maximum Weighted Grade Point (WGP) is 25

Components	Weight (W)	Grade Awarded	Grade Point(GP)	WGP=W *GP	Overall Grade of the Course
Comprehensive viva-voce	5	A+	5	25	**WGP/Total Weight = 25/ 5 = 5**
Total	**5**			**25**	**A+**

2. Evaluation Second stage-(to be done by the College)

Consolidation of the Grade(GPA) of a Course PC-1

The End Semester Evaluation (ESE) (External evaluation) grade awarded for the course PC-1 is A and its Continuous Evaluation (CE) (Internal Evaluation) grade is A. The consolidated grade for the course PC-1 is as follows

Evaluation	Weight	Grade awarded	Grade Points awarded	Weighted Grade Point
External	3	A	4.20	12.6
Internal	1	A	4.40	4.40
Total	**4**			**17**
Grade of a course.	GPA of the course =Total weighted Grade Points/Total weight= **17/4 =4.25 = Grade A**			

3. Evaluation Third stage-(to be done by the College)

Semester Grade Point Average (SGPA)

Course code	Titleof the course	Credits (C)	Grade Awarded	Grade Points(G)	Credit Points (CP=C X G)
01	**PC-1**	**5**	**A**	**4.25**	**21.25**
02	**-----**	**5**	**A**	**4.00**	**20.00**
03	**-----**	**5**	**B+**	**3.80**	**19.00**
04	**-----**	**2**	**A**	**4.40**	**8.80**
05	**-----**	**3**	**A**	**4.00**	**12.00**
TOTAL		**20**			**81.05**
SGPA	**Total credit points / Total credits = 81.05/20 = 4.05= Grade- A**				

4. **Evaluation Third stage-(to be done by the College)**

Cumulative Grade Point Average (CGPA)

If a candidate is awarded three **A+** grades in semester 1(SGPA of semester 1), semester 2(SGPA of semester 2), semester 4(SGPA of semester 4) and **B** grades in semester 3(SGPA of semester 3). Then CGPA is calculated as follows:

Semester	Credit of the Semesters	Grade Awarded	Grade point (SGPA)	Credit points
I	20	A+	4.50	90
II	20	A+	4.60	92
III	20	B	3.00	60
IV	20	A+	4.50	90
TOTAL	**80**			**332**
CGPA= Total credit points awarded / Total credit of all semesters = 332 / 80= 4.15 **(Which is in between 4.00 and 4.49 in 7-point scale)** **Therefore the overall Grade awarded in the programme is A**				

Introduction

The Department of Mathematics is committed to exemplary teaching and learning, scholarship and service. Our courses are designed to prepare every student with the technical background they will need and inculcate a love for the *VERITAS* of logical thought and elegant reasoning. The PG programme in mathematics is a two year full time programme with each year comprising of two semesters which is framed using time tested and internationally popular text books so that the courses are at par with the courses offered by any other reputed university around the world. As a part of our educational mission our department consists of scholarly and caring faculty members, each faculty member having the awareness of current developments in mathematics and mathematical pedagogy with many faculty members contributing research publications. The M. Sc. Programme is carefully designed to impart the essential knowledge in mathematics with opportunities for specialization in all major areas of pure and applied mathematics. In the first three semesters the focus is on core courses. In the last semester the students have the option to choose courses from a list of elective courses. Comprehensive *viva-voce* and project dissertations are integral part of the programme.

ELIGIBILITY FOR ADMISSION

Academic eligibility should be satisfied as on the last date of submission of academic data. No candidate shall be admitted to the PG programme unless he/she possess the qualifications and minimum requirements thereof, as prescribed by Mahatma Gandhi University from time to time.

If an applicant for admission is found to have indulged in ragging in the past or if it is noticed later that he/she had indulged in ragging, admissions shall be denied or he/she will be expelled from Mar Athanasius College (Autonomous), Kothamangalam.

Candidates should have passed the corresponding Degree Examination under the 10 + 2 + 3 pattern with one core/main subject and two complementary/subsidiary subjects from any of the Universities in Kerala or of any other University recognized by Mahatma Gandhi University as equivalent thereto for admission, subject to the stipulation regarding marks.

OR

Candidates who have passed Degree examination with Double or Triple main subject and candidates who have passed the Degree Examination in Vocational or Specialized Programmes are also eligible for admission. However, they have to submit copy of the Equivalency/Eligibility Certificate from Mahatma Gandhi University, stating that, their Qualifying Examination is recognized for seeking admission to the relevant P.G. Degree Programme(s) as applicable, at the time of admission. This provision is not applicable in the case of those applicants who have passed their qualifying examination from MG University.

The minimum requirements for admission to PG Degree Programme

M.Sc. Mathematics

Graduates who have passed qualifying examination in CBCS (2017)/CBCSS (2013) pattern	**Graduates who have passed qualifying examination in CBCSS (2009) pattern**	**Graduates who have passed qualifying examination in other patterns**
Graduation in Mathematics/Statistics/Computer Application with not less than CGPA/CCPA of 5.00 out of 10. 00 in the Core Group (Core + Complementary + Open Courses)	Graduation in Mathematics/ Statistics/Computer Application with not less than CGPA of 2.00 out of 4. 00 in the Core Group (Core + Complementary + Open Courses)	Graduation in Mathematics/ Statistics /Computer Application with not less than 50% marks in the Part III subjects (Main/Core+ subsidiaries/Complementaries)
OR B Tech with not less than 50% marks in mathematics (aggregate of all mathematics papers and a total of 50% for the entire course)		
No weightage marks.		

The Open course under core group is taken only for reckoning the eligibility for applying for the PG programmes concerned. But a candidate cannot apply for the respective PG programmes solely on the basis of the open course selected under core group.

Relaxation in Marks in the qualifying examination:

(i) **Kerala Scheduled Caste/Scheduled Tribe Category**: The minimum grade in the qualifying examination for admission to the PG Degree programme is 'C' in the Seven Point Scale for CBCSS and a pass for pre CBCSS applicants.

(ii) **SEBC Category**: A relaxation of 3% marks in the qualifying examination from the prescribed minimum is allowed i.e. CGPA of 4.2 for CBCS (2017), CCPA of 4.2 for CBCSS (2013), CGPA of 1.68 for CBCSS (2009) applicants and 42% marks for pre-CBCSS applicants for admission to M.Com Marketing and International Business Programme.

(iii) **OEC Category:** A relaxation of 5% marks in the qualifying examination from the prescribed minimum is allowed i.e. CGPA of 4.0 for CBCS (2017), CCPA of 4.0 CBCSS (2013), CGPA of 1.60 for CBCSS (2009) applicants and 40% marks for pre CBCSS applicants for admission to M.Com Marketing and International Business Programme.

(iv) **Persons with Disability category**: A relaxation of 5% marks in the qualifying examination from the prescribed minimum is allowed i.e. CGPA of 4.0 for CBCS (2017), CCPA of 4.0 for CBCSS (2013), CGPA of 1.60 for CBCSS (2009)applicants and 40% marks for pre CBCSS applicants for admission to for admission to M.Com Marketing and International Business Programme

POSTGRADUATE PROGRAMME OUTCOME

PO No.	Upon completion of Postgraduate programme, the students acquire:
PO-1	Sensible understanding about various precepts of the discipline, in synchronic and diachronic manner.
PO-2	Critical thinking about what they learn, that prompts them to research about its technical and philosophical nuances.
PO-3	Inter-personal skills enabling them to work in teams, facilitating effective interaction in their respective work places.
PO-4	Environmental and social consciousness, leading to a sustainable living.
PO-5	An urge for lifelong learning towards professional advancement and kindle the spirit of entrepreneurship.

MSc. MATHEMATICS PROGRAMME

PROGRAMME SPECIFIC OUTCOMES (PSO)

PSO No.	Upon completion of M.Sc Mathematics Programme, the students acquire:	PO No.
PSO-1	Good theoretical insight, creative and logical mind for formulating, analyzing and solving mathematical ideas and arguments.	**1,2**
PSO-2	Advanced abstract mathematical thinking capability and good knowledge in broad range of methods and techniques for analysing and solving problems in Mathematics	**1,2**
PSO-3	Advanced knowledge and fundamental understanding of a number of specialist mathematical topics.	**1,2**
PSO-4	Skill to do project works independently and pursue higher studies towards the Ph.D. degree in mathematics	**1,2,5**
PSO-5	Proficiency to take up jobs as teacher in Mathematics.	**1,2,3**
PSO-6	Thorough knowledge to prepare themselves for the CSIR NET, GATE and SET examinations	**1,2,5**
PSO-7	Self-learning and life-long learning skills, ethical values, self-discipline, environmental and social consciousness.	**3,4,5**

M.Sc. MATHEMATICS PROGRAMME

Sl. No	Course code	Name of the course	Type of Course	Hours per week	Credits
Semester – 1					
1	PG20MT101	Linear Algebra	Theory	5	4
2	PG20MT102	Abstract Algebra	Theory	5	4
3	PG20MT103	Real Analysis	Theory	5	4
4	PG20MT104	Graph Theory	Theory	5	4
5	PG20MT105	Basic Topology	Theory	5	4
Semester – 2					
6	PG20MT206	Complex Analysis	Theory	5	4
7	PG20MT207	Advanced Topology	Theory	5	4
8	PG20MT208	Theory of Ordinary Differential Equations	Theory	5	4
9	PG20MT209	Multivariable Calculus	Theory	5	4
10	PG20MT210	Number Theory and Cryptography	Theory	5	4
Semester – 3					
11	PG20MT311	Measure Theory and Integration	Theory	5	4
12	PG20MT312	Functional Analysis	Theory	5	4
13	PG20MT313	Differential Geometry	Theory	5	4
14	PG20MT314	Partial Differential Equation	Theory	5	4
15	PG20MT315	Optimization Techniques	Theory	5	4
Semester – 4					
16	PG20MT416	Spectral Theory	Theory	5	4
17	PG20MT417	Operations Research	Theory	5	4
18		Elective 1	Theory	5	3
19		Elective 2	Theory	5	3
20		Elective 3	Theory	5	3
Dissertation					1
Comprehensive Viva					2

Elective Courses					
Sl. No	**Course code**	**Name of the course**	**Type of Course**	**Hours per week**	**Credits**
Group A					
1	PG20MT418	Probability Theory	Theory	5	3
2	PG20MT419	Coding Theory	Theory	5	3
3	PG20MT420	Computer Methods	Theory	5	3
Group B					
1	PG20MT421	Combinatorics	Theory	5	3
2	PG20MT422	Analytic Number Theory	Theory	5	3
3	PG20MT423	Mathematical Economics	Theory	5	3
Group C					
1	PG20MT424	Advanced Complex Analysis	Theory	5	3
2	PG20MT425	Commutative Algebra	Theory	5	3
3	PG20MT426	Algorithmic Graph Theory	Theory	5	3
Group D					
1	PG20MT427	Lie Algebras	Theory	5	3
2	PG20MT428	Algebraic Topology	Theory	5	3
3	PG20MT429	Fractal Geometry	Theory	5	3
Group E					
1	PG20MT430	Financial Mathematics	Theory	5	3
2	PG20MT431	Theory of Wavelets	Theory	5	3
3	PG20MT432	Classical Mechanics	Theory	5	3

SEMESTER I

Semester I	Code: PG20MT101	LINEAR ALGEBRA	Total Hrs:**90**	Credits: **4**
			Hrs/Week:**5**	

Course Objective

- Understand basic concepts of linear algebra - system of linear equations, matrix calculus, vectors and basic vector operations
- Solve system of linear algebraic equations
- Attain skills and gain knowledge about canonical forms, characteristic values, triangulation and diagonalisation.
- Develop a thorough knowledge about annihilators, triangulation, diagonalization and decomposition.
- Gains a knowledge of the different decompositions.

Syllabus

Module 1: **VECTOR SPACES AND LINEAR TRANSFORMATIONS**
Vector spaces, subspaces, basis and dimension, Co-ordinates
(Chapter 2, 2.1, 2.2, 2.3, 2.4 of the text) (Proof of theorems excluded)
Linear transformations, the algebra of linear transformations, isomorphism, representation of transformations by matrices, linear functionals, double dual, transpose of a linear transformation.
(Chapter 3 - 3.1, 3.2, 3.3, 3.4, 3.5, 3.6 & 3.7 of the text) **(25 hours)**

Module 2: **DETERMINANTS**
Commutative Rings, Determinant functions, Permutation and uniqueness of determinants, Additional properties of determinants.
(Chapter 5 - 5.1, 5.2, 5.3 & 5.4 of the text) **(20 hours)**

Module 3: **ELEMENTARY CANONICAL FORMS**
Introduction to elementary canonical forms, characteristic values, annihilatory polynomials, invariant subspaces, simultaneous triangulations, simultaneous diagonalisation, direct sum decompositions, invariant direct sums
(Chapter 6 - 6.1, 6.2, 6.3, 6.4, 6.5 & 6.6 of the text) **(25 hours)**

Module 4: **PRIMARY DECOMPOSITION AND JORDAN FORM**
The Primary Decomposition Theorem, Cyclic Subspaces and Annihilators, Cyclic Decompositions and Rational Form, The Jordan Form
(Chapter 6 - 6.7, Chapter 7- 7.1, 7.2, 7.3, of the text) (Proof of Cyclic Decomposition theorem excluded) **(20 hours)**

Text Books:

1. **Kenneth Hoffman / Ray Kunze (Second Edition), *Linear Algebra*, Prentice-Hall of India Pvt. Ltd., New Delhi, 1992.**

References:

1. S. Friedberg, A. Insel, L. Spencer, Linear Algebra, Pearson Edu Ltd. 2014.

2. Paul R. Halmos, Linear Algebra Problem Book, The Mathematical Association of America, 1995.
3. S. Kumaresan, Linear Algebra A Geometrical Approach, Prentice Hall of India, 2000.

QUESTON PAPER PATTERN

Module	Part A (Wt. : 1) Short Answer	Part B (Wt. : 2) Short Essay	Part C (Wt. : 5) Long Essay	Total
I	2	2	1	**5**
II	3	3	1	**7**
III	3	1	1	**5**
IV	2	2	1	**5**
Total No. of Questions	**10**	**8**	**4**	**22**
No. Questions to be answered	**8**	**6**	**2**	**16**

Course Outcomes

CO No.	Upon completion of this course, the students will be able to:	Knowledge Level
1	Develops algebraic and computational skills needed to study vector spaces, linear transformations, representation of transformation as a matrix.	K6, K4
2	Analyze finite and infinite dimensional vector spaces and subspaces over a field and their properties, including the basis structure of vector spaces	K4
3	Facilitate to use the definition and properties of linear transformations and matrices of linear transformations and change of basis	K6
4	Identify and operate determinants, permutations and their properties	K1,K2, K3
5	Explain the concepts of canonical forms, characteristic values, triangulation and diagonalisation	K2
6	Integrate different decompositions of linear equations	K6
Knowledge Levels: K1-Remembering; K2-Understanding; K3-Applying; K4-Analyzing; K5-Evaluating; K6-Creating.		

Learning Pedagogy

Chalk and talk, Multimedia projection, e-content, Group discussion, Seminar, Interactive sessions, Tutorials, Assignment, Quiz, LMS

Assessment Tools

Assignments, Seminar, Test papers, End semester examination, Online test and assignments

Semester I	Code: PG20MT102	ABSTRACT ALGEBRA	Total Hrs:**90** Hrs/Week:**5**	Credits: **4**

Course Objective

- To introduce students to the language and precision of modern abstract algebra with a sufficient base of examples.
- Make student understand and prove fundamental results and solve problems on some of the algebraic structures using appropriate techniques
- Develop skill and gain experience and confidence in proving theorems.
- Attain an understanding and gain knowledge of the concepts of rings and fields and their properties.
- Gain clear knowledge of the concepts of homomorphisms and isomorphisms, their properties and Galois Theory

Syllabus

Module 1: Direct products and finitely generated Abelian groups, fundamental theorem (without proof), applications. Rings of polynomials, the evaluation homomorphisms, Factorisation of polynomials over a field, Irreducible Polynomials, Eisenstein Criterion
(Part II – Section 11) & (Part IV – Sections 22 & 23) **(25 hours)**

Module 2: Introduction to extension fields, Algebraic and Transcendental Elements, Irreducible Polynomials over F, Algebraically closed fields, algebraic extensions, Geometric constructions, Finite fields.
(Part VI – Section 29, 31 – 31.1 to 31.18, 32, 33) **(25 hours)**

Module 3: Sylow's theorems (without proof), Applications of sylow theory Automorphism of fields, the isomorphism extension theorem (proof of the theorem excluded)
(Part VII Sections 36 & 37) (Part X – Sections 48 & 49, (49.1 to 49.5) **(20 hours)**

Module 4: Splitting fields, separable extensions, Perfect fields, The Primitive Element Theorem, Galois theory
(Part X – Sections 50, 51, 53 -53.1 to 53.6) **(20 hours)**

Text Books:

1. **John B. Fraleigh, A First Course in Abstract Algebra, 7th edition, Pearson Education, 2003.**

References:

1. I.N. Herstein, Topics in Algebra, Wiley Eastern Ltd., New Delhi, 1975.
2. M. Artin, Algebra, Prentice -Hall of India, 1991
3. N. Jacobson, Basic Algebra Vol. I, Hindustan Publishing Corporation, 1984.
4. P.B. Bhattacharya, S.K. Jain, S.R. Nagapaul, Basic Abstract Algebra, 2nd edition, Cambridge University Press, Indian Edition, 1997.

QUESTON PAPER PATTERN

Module	Part A (Wt. : 1) Short Answer	Part B (Wt. : 2) Short Essay	Part C (Wt. : 5) Long Essay	Total
I	3	2	1	**6**
II	3	2	1	**6**
III	2	2	1	**5**
IV	2	2	1	**5**
Total No. of Questions	**10**	**8**	**4**	**22**
No. Questions to be answered	**8**	**6**	**2**	**16**

Course Outcomes

CO No.	Upon completion of this course, the students will be able to:	Knowledge Level
1	Demonstrate knowledge of identifying group homomorphism, isomorphism, automorphism, conjugates, Class Equation and Sylow theorems.·	K1,K3
2	Derive and apply Sylow Theorems.	K4,K6
3	Demonstrate knowledge of polynomial rings and associated properties.	K4
4	Derive and apply Gauss Lemma, Einstein criterion for irreducibility of rationals.	K3
5	Explain the characteristic of a field and the prime subfield.	K3
6	Develop knowledge on Field extensions, characterization of finite normal extensions as splitting fields, structure and construction of finite fields and Galois theory.	K5
Knowledge Levels: K1-Remembering; K2-Understanding; K3-Applying; K4-Analyzing; K5-Evaluating; K6-Creating.		

Learning Pedagogy

Chalk and talk, Multimedia projection, e-content, Group discussion, Seminar, Interactive sessions, Tutorials, Assignment, Quiz, LMS

Assessment Tools

Assignments, Seminar, Test papers, End semester examination, Online test and assignments

Semester I	Code: PG20MT103	REAL ANALYSIS	Total Hrs:**90**	Credits: **4**
			Hrs/Week:**5**	

Course Objective

- Help students to develop an understanding of familiar theorems like Heine- Borel theorem, Baire Category theorem and Ascoli -Arzela theorem.
- Understand the difference between uniform and point wise convergence of sequence of functions.
- Equip students with the concepts of bounded variation, rectifiable curves and Riemann Stieltjes integral.

Syllabus

Module 1: **Metric Spaces**
Introduction, Open and Closed sets, Continuous functions and Homomorphism, Convergence and completeness. Uniform continuity and uniformity, Subspaces, Compact metric spaces, Baire Category, Absolute G_δ's The Ascoli-Arzela Theorem
(Chapter 7- Sections 1 to10 of Text 1.) **(25 hours)**

Module 2: **Sequence and Series of Functions**
Discussion of main problem, uniform convergence, uniform convergence and continuity, uniform convergence and integration, uniform convergence and differentiation, the Stone-Weierstrass theorem (without proof).
(Chapter 7 Section. 7.7 to 7.18 of Text 2) **(25 hours)**

Module 3: **Functions of bounded variation and rectifiable curves**
Introduction, properties of monotonic functions, functions of bounded variation, total variation, additive property of total variation, total variation on (a, x) as functions of x, functions of bounded variation expressed as the difference of increasing functions, continuous functions of bounded variation, curves and paths, rectifiable path and arc length, additive and continuity properties of arc length, equivalence of paths, change of parameter.
(Chapter 6, Section: 6.1 - 6.12. of Text 3) **(20 hours)**

Module 4: **The Riemann-Stieltjes Integral**
Definition and existence of the integral, properties of the integral, integration and differentiation, integration of vector valued functions.
(Chapter 6 - Section 6.1 to 6.25 of Text 2) **(20 hours)**

Text Books:

1. **H L Royden, Real analysis, (Third Edition) Dorling Kinderslitn & Person Education, 1963.**
2. **Walter Rudin, Principles of Mathematical Analysis (Third edition), International Student Edition, 1964.**
3. **Tom Apostol, Mathematical Analysis (second edition), Narosa Publishing House, 2013.**

References:

1. Royden H.L, Real Analysis, 2nd edition, Macmillan, New York.
2. Bartle R.G, The Elements of Real Analysis, John Wiley and Sons, 1964.
3. S.C. Malik, Savitha Arora, Mathematical Analysis, New Age International Ltd, 1992.
4. Edwin Hewitt, Karl Stromberg, Real and Abstract Analysis, Springer International, 1978.

QUESTON PAPER PATTERN

Module	Part A (Wt. : 1) Short Answer	Part B (Wt. : 2) Short Essay	Part C (Wt. : 5) Long Essay	Total
I	2	2	1	**5**
II	3	2	1	**6**
III	2	2	1	**5**
IV	3	2	1	**6**
Total No. of Questions	**10**	**8**	**4**	**22**
No. Questions to be answered	**8**	**6**	**2**	**16**

Course Outcomes

CO No.	Upon completion of this course, the students will be able to:	Knowledge Level
1	Explain metric spaces and related properties like uniform convergence, Equicontinuity etc.	K3
2	Describe Heine-Borel theorem , Baire Category Theorem and Ascoli- Arzela Theorem	K1, K2
3	Distinguish between uniform convergence and point wise convergence of sequence and series of functions.	K2, K4
4	Combine functions of bounded variation and rectifiable curves	K6
5	Define properties of Riemann Stieltjes Integral and Differentiation	K1
Knowledge Levels: K1-Remembering; K2-Understanding; K3-Applying; K4-Analyzing; K5-Evaluating; K6-Creating.		

Learning Pedagogy

Chalk and talk, Multimedia projection, e-content, Group discussion, Seminar, Interactive sessions, Tutorials, Assignment, Quiz, LMS

Assessment Tools

Assignments, Seminar, Test papers, End semester examination, Online assignments and tests

Semester I	Code: PG20MT104	GRAPH THEORY	Total Hrs:**90**	Credits: **4**
			Hrs/Week:**5**	

Course Objective

- Understand basic concepts of graph theory and use graph theory as a modeling tool
- Equip students with the concepts of matching, graph coloring, planarity and domination in graphs.

Syllabus

Quick Review: Graph, Degrees of vertices, Paths and connectedness, Vertex cuts and edge cuts, Connectivity and edge connectivity, Trees - characterization and simple properties. **(4 hours)**

Module 1: **INDEPENDENT SETS AND MATCHINGS, EULERIAN AND HAMILTONIAN GRAPHS**

Introduction, Vertex-independent sets and vertex coverings, Edge-independent sets, Matching's and factors, Matching's in bipartite graphs, Eulerian graphs, Hamiltonian graphs.

(Chapter 5 Sections 5.1-5.5, Chapter 6 Sections 6.1-6.3) (24 Hours)

Module 2: **GRAPH COLOURINGS**

Vertex coloring's, Critical graphs, Brooks' theorem, Edge coloring's of graphs, Vizing's theorem.

(Chapter 7, Sections 7.2.1, 7.3, 7.3.1, 7.6.1, 7.6.2) (22 Hours)

Module 3: **PLANARITY**

Planar and non planar graphs, Euler formula and its consequences, K_5 and $K_{3,3}$ are non planar graphs, Dual of a plane graph, The Four colour theorem and the Heawood Five - colour theorem, Kuratowski's theorem, Hamiltonian plane graphs. **(Chapter 8, Sections 8.1 - 8.8 (Theorems 8.7.4 and 8.7.5 - statements only) (20 Hours)**

Module 4: **DOMINATION IN GRAPHS**

Introduction, Domination in graphs, Bounds for the domination number, Bound for the size m in terms of order n and domination number $\gamma(G)$, Independent domination and Irredundance.

(Chapter 10, Sections 10.1 - 10.6) (20 Hours)

Text Books:

1. **R Balakrishnan and K Ranganathan: A Textbook of Graph Theory, Second Edition, Springer, 2000.**

References:

1. Frank Harary, Graph Theory, Addison-Wesley Publishing Company, Inc 1969.
2. Teresa W Haynes, Stephen Hedetniemi, Peter Slater, Fundamentals of Domination in Graphs, Crc Press, 1998.

Course Outcomes

CO No.	Upon completion of this course, the students will be able to:	Knowledge Level
1	Understand the definitions namely, independent sets, matchings and coverings.	K2
2	Distinguish Eulerian and Hamiltonian graphs and apply results to identify these graphs.	K5
3	Formulate the properties of graph colourings.	K6
4	Understand the concepts Planarity and formulate Euler identity.	K2, K6
5	Expalin the importance of the concepts of Domination in Graphs.	K3
Knowledge Levels: K1-Remembering; K2-Understanding; K3-Applying; K4-Analyzing; K5-Evaluating; K6-Creating.		

QUESTON PAPER PATTERN

Module	Part A (Wt. : 1) Short Answer	Part B (Wt. : 2) Short Essay	Part C (Wt. : 5) Long Essay	Total
I	3	2	1	**6**
II	2	2	1	**5**
III	3	2	1	**6**
IV	2	2	1	**5**
Total No. of Questions	**10**	**8**	**4**	**22**
No. Questions to be answered	**8**	**6**	**2**	**16**

Learning Pedagogy

Chalk and talk, Multimedia projection, e-content, Group discussion, Seminar, Interactive sessions, Tutorials, Assignment, Quiz, LMS

Assessment Tools

Assignments, Seminar, Test papers, End semester examination, Online assignments and tests

Semester I	Code: PG20MT105	BASIC TOPOLOGY	Total Hrs:**90** / Hrs/Week:**5**	Credits: **4**

Course Objective

- To provide the student with an intense foundation in fundamental concepts of point-set topology
- Understand the definitions of concepts like separation axioms and construct example and counter examples
- Provide adequate language for advanced studies of mathematics, and developing skills in woking with abstract concepts like connectedness and compactness.

Syllabus

Module 1: Definition of a topological space – examples of topological spaces, bases and sub bases – sub spaces.Basic concepts: closed sets and closure –neighborhood, interior and accumulation points **(Chapter 4 Section – 1, 2, 3, 4 - Chapter 5 Section - 1 and 2 of the text.5.2.11 & 5.2.12 excluded.)** **(24 hours)**

Module 2: Continuity and related concepts: making functions continuous, quotient spaces. Spaces with special properties: Smallness condition on a space (Chapter 5. Section. 3 and 4 of the text, 5.3.2(4) excluded)
(Chapter 6 Sec. 1 of the text) **(22 hours)**

Module 3: Connectedness: Heine-Borel theorem,Separated sets ,Components of a space, Local connectedness, the hereditary and divisible properties of locally connected space, paths and path connectedness,the relation between path connectedness and connectedness.
(Chapter 6 Section. 2 & 3 of the text) **(22 hours)**

Module 4: Separation axioms: The different types of separation axioms,Hierarchy of separation axioms ,metric spaces and separation axioms, compactness and separation axioms,Wallace's theorem. **(Chapter – 7 Section 1 & 2 of the text)(2.13 to 2.16 of section.2 excluded)** **(22 hours)**

Text Books:

1. **K.D. Joshi, Introduction to General Topology, Wiley Eastern Ltd, 1984.**

References:

1. Munkres J.R, Topology-A First Course, Prentice Hall of India Pvt. Ltd., New Delhi, 2000.
2. J.L Kelley, General Topology, Van Nostrand, Reinhold Co., New York, 1995.
3. Stephen Willard, General Topology, Addison-Wesley, 2004.
4. Dugundji, Topology, Universal Book Stall, New Delhi, 1989.
5. George F Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill Book Company, 1963.

QUESTON PAPER PATTERN

Module	Part A (Wt. : 1) Short Answer	Part B (Wt. : 2) Short Essay	Part C (Wt. : 5) Long Essay	Total
I	3	2	1	**6**
II	3	2	1	**6**
III	2	2	1	**5**
IV	2	2	1	**5**
Total No. of Questions	**10**	**8**	**4**	**22**
No. Questions to be answered	**8**	**6**	**2**	**16**

Course Outcomes

CO No.	Upon completion of this course, the students will be able to:	Knowledge Level
1	Develop their abstract thinking skills.	K3,K6
2	Produce precise definitions and appropriate examples and counter examples of fundamental concepts in general topology.	K1, K3,K6
3	Define and illustrate the concept of topological spaces and continuous functions	K1, K2
4	Describe and explain the concept of product topology and quotient topology	K1,K2
5	State connectedness and compactness, and prove a selection of related theorems	K1
6	Identify and give examples of spaces satisfying different separation axioms.	K1, K2
Knowledge Levels: K1-Remembering; K2-Understanding; K3-Applying; K4-Analyzing; K5-Evaluating; K6-Creating.		

Learning Pedagogy

Chalk and talk, Multimedia projection, e-content, Group discussion, Seminar, Interactive sessions, Tutorials, Assignment, Quiz, LMS

Assessment Tools

Assignments, Seminar, Test papers, End semester examination, Online assignments and tests

SEMESTER 2

Semester **II**	Code: **PG20MT206**	**COMPLEX ANALYSIS**	Total Hrs:**90** Hrs/Week:**5**	Credits: **4**

Course Objective

- Develop an understanding of analytic functions and conformal mappings
- Represent analytic functions in power series form.
- Ability to integrate complex functions by counting zeroes and poles
- Familiarize classical theorems like Cauchy's theorem, Residue theorem, and Argument Principle.

Syllabus

Module 1: Elementary Properties and Examples of Analytic functions:
Power Series, Analytic Functions, Analytic functions as mappings, Mobius transformations
(Chapter 3 of the text) **(20 hours.)**

Module 2: Complex Integration:
Power series representation of analytic functions, zeros of an analytic function, the index of a closed curve, Cauchy's theorem and Integral Formula
(Chapter 4 – Sections 1, 2, 3 and 4. of the text.) **(25 hours.)**

Module 3: The homotopic version of Cauchy's Theorem, simple connectivity, Counting zeros; the Open Mapping Theorem, Goursat's Theorem
(Chapter 4 – Sections 5,6,7 and 8 of the text) **(25 hours.)**

Module 4: Singularities:
Classification of singularities, Residues, The Argument Principle, The Maximum Principle, Schwarz's Lemma
(Chapter 5 – Sections 1, 2, 3, Chapter 6 sections 1 and 2 of the text)
(20 hours.)

Text Books:

1. **Conway J.B, Functions of one Complex variable, Narosa publishing, 2012.**

References:

1. Lars V. Ahlfors, Complex Analysis, Third edition, McGraw Hill Internationals, 1998.
2. Chaudhary. B, The elements of Complex Analysis, Wiley Eastern, 2006.
3. Lang. S, Complex Analysis, Springer, 2013.
4. H.A. Priestly, Introduction to Complex Analysis, Clarendon press, Oxford, 1990.
5. George F Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill Book Company, 1963.

QUESTON PAPER PATTERN

Module	Part A (Wt. : 1) Short Answer	Part B (Wt. : 2) Short Essay	Part C (Wt. : 5) Long Essay	Total
I	3	2	1	**6**
II	3	2	1	**6**
III	2	2	1	**5**
IV	2	2	1	**5**
Total No. of Questions	**10**	**8**	**4**	**22**
No. Questions to be answered	**8**	**6**	**2**	**16**

Course Outcomes

CO No.	Upon completion of this course, the students will be able to:	Knowledge Level
1	Describe local properties of Analytic functions.	K2
2	State topological and geometrical properties of complex plane.	K1
3	Develop functions as power series and classify singularities	K3,K6
4	Apply Cauchy's theorem and integral formula for disks .	K3
5	Integrate complex functions by counting zeroes and poles.	K6
6	Explain Residue theorem and Argument principle	K4
Knowledge Levels: K1-Remembering; K2-Understanding; K3-Applying; K4-Analyzing; K5-Evaluating; K6-Creating.		

Learning Pedagogy

Chalk and talk, Multimedia projection, e-content, Group discussion, Seminar, Interactive sessions, Tutorials, Assignment, Quiz, LMS

Assessment Tools

Assignments, Seminar, Test papers, End semester examination, Online assignments and tests

Semester II	Code: PG20MT207	ADVANCED TOPOLOGY	Total Hrs:**90** Hrs/Week:**5**	Credits: **4**

Course Objective

- Understand definitions; construct examples and counterexamples based on definitions
- Develop intuition regarding proofs, make arguments based on logic
- Describe the concepts like product spaces, nets, filters and properties of various forms of compactness.

Syllabus

Module 1: Urysohn Characterisation of Normality – Tietze Characterisation of Normality. **(Chapter 7 Section-.3 and 4 of the text.)(Proof of 3.4, 4.4, and 4.5 excluded)**
Products and co-products: Cartesian products of families of sets – Product Topology – Productive properties. **(Chapter 8 Section. 1, 2 & 3 of the text) (proof of 1.6 &1.7 excluded)** **(25 hours)**

Module 2: Embedding and Metrisation – Evaluation Functions in to Products, Embedding Lemma and Tychnoff Embedding, The Urysohn Metrization theorem.
(Chapter 9. Sec. 1, 2 & 3 of the text) **(15 hours)**

Module 3: Nets and Filters: Definition and Convergence of Nets, Topology and Convergence of Nets, Filters and their Convergence, Ultra filters and Compactness.
(Chapter – 10 Sections -1, 2, 3 & 4 of the text) **(25 hours)**

Module 4: Compactness: Variations of compactness – local compactness – compactification.
Chapter 11. Section 1 (Proof of theorem 1.4 & 1.12 excluded), Section 3, Section 4 (from 4.1 to 4.7) of the text **(25 hours)**

Text Books:

1. **K.D. Joshi, Introduction to General Topology, Wiley Eastern Ltd.**

References:

1. Munkres J.R, Topology-A First Course, Prentice Hall of India Pvt. Ltd., New Delhi, 2000.
2. J.L Kelley, General Topology, Van Nostrand, Reinhold Co., New York, 1995.
3. Stephen Willard, General Topology, Addison-Wesley, 2004.
4. Dugundji, Topology, Universal Book Stall, New Delhi, 1989.
5. George F Simmons, Introduction to Topology and Modern Analysis, McGraw-Hill Book Company, 1963.

QUESTON PAPER PATTERN

Module	Part A (Wt. : 1) Short Answer	Part B (Wt. : 2) Short Essay	Part C (Wt. : 5) Long Essay	Total
I	3	2	1	**6**
II	2	1	1	**4**
III	3	3	1	**7**
IV	2	2	1	**5**
Total No. of Questions	**10**	**8**	**4**	**22**
No. Questions to be answered	**8**	**6**	**2**	**16**

Course Outcomes

CO No.	Upon completion of this course, the students will be able to:	Knowledge Level
1	Illustrate product topology by constructing suitable examples	K2, K3,K6
2	Describe and explain Tietze characterisation of Normality.	K1,K2,K4
3	consider Evaluation Functions in to Products	K5
4	Interpret Compactness, Nets and Filters, produce examples and counter example for various properties	K3,K6
Knowledge Levels: K1-Remembering; K2-Understanding; K3-Applying; K4-Analyzing; K5-Evaluating; K6-Creating.		

Learning Pedagogy

Chalk and talk, Multimedia projection, e-content, Group discussion, Seminar, Interactive sessions, Tutorials, Assignment, Quiz, LMS

Assessment Tools

Assignments, Seminar, Test papers, End semester examination, Online assignments and tests

Semester II	Code: PG20MT208	THEORY OF ORDINARY DIFFERENTIAL EQUATIONS	Total Hrs:**90**	Credits: **4**
			Hrs/Week:**5**	

Course Objective

- Understand the concepts relating to ODE and the applying it to model and solve real life problems.
- Understand the existence and uniqueness of the initial value problem.
- Apply the concepts of linear algebra to find solutions of linear and non-linear systems.
- Understand the application of Jordan decomposition in the theory of stability analysis.

Syllabus

Module 1: **Introduction to Ordinary Differential Equations**

Revision of Linear Algebra: **(Sections 2.4 - 2.7 of Book1.)**
Mathematical modeling using ODE's: Population dynamics, Spring-Mass-Damper model etc., motivation to do analysis of ODE's
Definition of Linearity, Classification of ODE's: Linear and nonlinear, homogeneous and non-homogeneous differential equations, order of differential equations
Notion of solution: General solution, particular solution, singular solution
Methods of solution for first order linear differential equations: Separation of variables, integrating factor
Second order linear differential equations:

- Homogeneous differential equations: solution space, linear dependence and independence of solutions and their Wronskian, solution of constant coefficient equations
- Non-homogeneous differential equation: complementary solution, particular solution, methods of undetermined coefficients and variation of parameters.
- Series solution: Equations with analytic coefficients, equations with regular singular points, Frobenius series solutions

(Sections 1.1, 1.2.1 - 1.2.3 of Book 1. Section 3.1 - 3.3 of Book 1, Sections 3.1 - 3.4 and 4.1 - 4.4 of Book 2.) **(20 hours)**

Module 2: **Existence and Uniqueness Theory**

Notion of solutions, well-posedness of IVP, Some examples on unique solution, infinitely many solutions and no solution of IVP – Lipschitz continuity, Gronwall's inequality and uniqueness of the solution of IVP , Picard's existence and uniqueness theorem for IVP, Peano existence theorem, Continuous dependence of solution on initial data, Continuation of solution and maximal interval of existence, Existence and uniqueness of solution of system of equations
(Chapter 4 of Book1) **(25 hours)**

Module 3: **Linear Systems Theory**

Reduction of nth order scalar differential into a system of n first order ODE's, Fundamental matrix solution, space of all solutions as n-dimensional vector

space, Transition matrix and solution of IVP, Autonomous systems and matrix exponential, Computation of matrix exponential for diagonal matrices, Jordan blocks and other special matrices, Solution of nonhomogeneous IVP by Duhamel's principle
(Sections 5.1 - 5.6 of Book2) **(20 hours)**

Module 4: **Stability of Linear and Nonlinear Systems**
Computation of matrix exponential, Two dimensional systems, Stability Analysis **(Sections 5.1 - 5.4 of Book1)**
Stability theory for 2×2 systems: canonical form, equilibrium points, node, center and focus, Classification of equilibrium points of nonlinear systems, Stability theory of nonlinear systems: Lyapunov stability, asymptotic stability and exponential stability **(Sections 8.1 - 8.4 of Book1)** **(25 hours)**

Text Books:

1. **A. K. Nandakumaran, P. S. Datti, R. K. George, Ordinary Differential Equations: Principles and Applications, Cambridge, 2017.**
2. **Tyn Myint-U, Ordinary Differential Equations, Elsevier North-Holland, 1978.**

References:

1. Differential Equations, George F Simmons, Steven G Krantz, Tata McGraw-Hill - 2011.
2. Differential Equations, Shepley L Ross, Wiley Student Edition. Third edition, 1980.

QUESTON PAPER PATTERN

Module	Part A (Wt. : 1) Short Answer	Part B (Wt. : 2) Short Essay	Part C (Wt. : 5) Long Essay	Total
I	3	2	1	**6**
II	3	2	1	**6**
III	2	2	1	**5**
IV	2	2	1	**5**
Total No. of Questions	**10**	**8**	**4**	**22**
No. Questions to be answered	**8**	**6**	**2**	**16**

Course Outcomes

CO No.	Upon completion of this course, the students will be able to:	Knowledge Level
1	Analyse ordinary differential equations (ODEs) and system of ODEs and employ them to design and solve various physical problems.	K3,K4,K6
2	Explain the notion of solution of an ODE and the methods to evaluate homogeneous as well as non-homogeneous ODEs of first and second order.	K2,K4,K5
3	Describe the existence and uniqueness of initial value problem and produce examples and counterexamples to justify the same.	K1,K6
4	Analyse and evaluate the stability of linear and non-linear systems ..	K4,K5
Knowledge Levels: K1-Remembering; K2-Understanding; K3-Applying; K4-Analyzing; K5-Evaluating; K6-Creating.		

Learning Pedagogy

Chalk and talk, Multimedia projection, e-content, Group discussion, Seminar, Interactive sessions, Tutorials, Assignment, Quiz, LMS

Assessment Tools

Assignments, Seminar, Test papers, End semester examination, Online assignments and tests

Semester II	Code: PG20MT209	MULTIVARIABLE CALCULUS	Total Hrs:**90** / Hrs/Week:**5**	Credits: **4**

Course Objective

- Examine functions of several variables, define and compute directional derivatives, total derivatives of the multivariable functions.
- Analyse the conditions for existence of absolute extreme values and classify the various extremum values.
- Describe the integrals of functions of several variables.

Syllabus

Module 1: **Differential Calculus**

Functions of several variables, Open sets, Limits and continuity, Derivatives of a scalar field with respect to a vector, Directional derivatives, Partial derivatives, Total derivative, Gradient of a scalar field, Level sets and tangent planes, Derivatives of vector fields, Chain rules for derivatives, Derivatives of functions defined implicitly, Higher order derivatives, Taylor's theorem.

(Chapter 8, Sections 9.6 - 9.8 of Book1) **(35 hours)**

Module 2: **Applications of Differential Calculus**

Maxima, Minima, Saddle points, Stationary points, Lagrange's multipliers, Inverse function theorem (no proof), Implicit function theorem (no proof)

(Sections 9.9 - 9.14 of Book1, Sections 13.3 - 13.4 of Book2) **(20 hours)**

Module 3: **Integration in One Variable**

Paths and line integrals, Fundamental theorems of calculus for line integrals, Vector fields and gradients.

(Sections 10.1 - 10.18 of Book1) **(10 hours)**

Module 4: **Integration in Several Variables**

Multiple Integrals: Double and triple integrals, Iterated integrals, Change of variables formula, Applications to area and volume, Green's theorem, Two-dimensional vector fields and gradients. Surface Integrals: Parametric representation of a surface, Fundamental vector product and normal to a surface, Stokes' theorem (no proof), Curl and divergence of a vector field, Gauss' divergence theorem (no proof).

(Sections 11.1 - 11.14, 11.19 - 11.22, 11.26 - 11.28, 12.1 - 12.13, 12.18 - 12.20 of Book1) **(25 hours)**

Text Books:

1. **T. M. Apostol, Calculus Vol. II, 2nd Ed., John Wiely & Sons, 2003.**
2. **T. M. Apostol, Mathematical Analysis, 2nd Ed., Narosa Pub. House, 1997**.

References:

1. Walter Rudin, Principles of Mathematical Analysis, Third edition –International Student Edition, 1964.
2. Limaye Balmohan Vishnu, Multivariate Analysis, Springer, 1992.

QUESTON PAPER PATTERN

Module	Part A (Wt. : 1) Short Answer	Part B (Wt. : 2) Short Essay	Part C (Wt. : 5) Long Essay	Total
I	3	3	1	**7**
II	3	2	1	**6**
III	2	1	1	**4**
IV	2	2	1	**5**
Total No. of Questions	**10**	**8**	**4**	**22**
No. Questions to be answered	**8**	**6**	**2**	**16**

Course Outcomes

CO No.	Upon completion of this course, the students will be able to:	Knowledge Level
1	Interpret the importance of fourier series and integral transform.	K3
2	Extend the derivative theory from the realm of real valued functions to vector valued functions.	K2
3	Recognise and review the relevance of total derivative over the usual partial derivatives and directional derivatives .	K1,K2
4	Analyse the implicit function theorem and extremum problems.	K4
5	Assess and appraise multiple integrals and differential forms.	K5,K4
Knowledge Levels: K1-Remembering; K2-Understanding; K3-Applying; K4-Analyzing; K5-Evaluating; K6-Creating.		

Learning Pedagogy

Chalk and talk, Multimedia projection, e-content, Group discussion, Seminar, Interactive sessions, Tutorials, Assignment, Quiz, LMS

Assessment Tools

Assignments, Seminar, Test papers, End semester examination, Online assignments and tests

Semester II	Code: PG20MT210	NUMBER THEORY AND CRYPTOGRAPHY	Total Hrs:**90** / Hrs/Week:**5**	Credits: **4**

Course Objective

- Define and interpret the concepts of divisibility, congruence, greatest common divisor and prime factorization.
- Apply the Law of Quadratic Reciprocity and their methods to classify numbers as quadratic residues and non-residues.
- Formulate cryptographic systems by using the concepts like discrete logarithm

Syllabus

Module 1: **Some topics in Elementary Number Theory**:-Time estimates for doing arithmetic, divisibility and the Euclidean algorithm, congruences, some applications to factoring.
(Chapter – I Sections 1, 2, 3 & 4 of the text) **(28 hours)**

Module 2: **Finite Fields and Quadratic Residues**:-Finite fields, Existence and uniqueness property of finite fields,Quadratic residues ,Legendre symbol,Reciprocity law,Jacobi symbol,Square root in modulo(p).
(Chapter – II Sections 1 & 2 of the text) **(14 hours)**

Module 3: **Public Key: -** The idea of public key cryptography, **RSA,** Discrete log. Diffe-Helmann assumption,Massey Omura Cryptosystem for message transmission,The ELGamal Cryptosystem,Digital signature standard,Silver - Pohlig algorithm,Index calculus algorithm
(Chapter – IV Sections 1, 2 & 3 of the text) **(25 hours)**

Module 4: **Primality and Factoring: -** Pseudoprimes, The rho method, Fermat factorization and factor bases, The quadratic sieve method.
(chapter – V Sections 1, 2, 3 & 5 of the text) **(23 hours)**

Text Books:

1. **Neal Koblitz, A Course in Number Theory and Cryptography, 2nd edition, Springer Verlag.**

References:

1. Niven, H.S. Zuckerman and H.L. Montgomery, *An introduction to the theory of numbers*, John Wiley, 5th Edition, 1991.
2. Ireland and Rosen, *A Classical Introduction to Modern Number Theory*. Springer, 2nd edition, 1990.
3. David Burton, *Elementary Number Theory and its applications,* McGraw-Hill Education (India) Pvt. Ltd, 2006.
4. Alfred J. Menezes, Paul C. van Oorschot and Scott A. Vanstone, *Handbook of Applied Cryptography*, CRC Press, 1996.
5. Victor Shoup, A computation Introduction to Number Theory and Algebra, Cambridge University Press, 2005.
6. William Stallings, *Cryptography and Network Security Principles and Practice*, Third edition, Prentice-hall, India, 2006.

Course Outcomes

CO No.	Upon completion of this course, the students will be able to:	Knowledge Level
1	Develop a deeper conceptual understanding of the theoretical basis of number theory and cryptography.	K3,K6
2	Apply number theory in cryptography.	K3
3	Describe Quadratic residues and Jacobi symbols.	K2
4	Illustrate the working method of various Public key cryptosystems.	K2,K3,K4
5	Facilitate Factorization of large numbers using Rho method and Fermat's Factorization.	K6
6	Associate the knowledge of discrete log problems as the basis of cryptography.	K2
Knowledge Levels: K1-Remembering; K2-Understanding; K3-Applying; K4-Analyzing; K5-Evaluating; K6-Creating.		

QUESTON PAPER PATTERN

Module	Part A (Wt. : 1) Short Answer	Part B (Wt. : 2) Short Essay	Part C (Wt. : 5) Long Essay	Total
I	4	3	1	**8**
II	1	1	1	**3**
III	3	2	1	**6**
IV	2	2	1	**5**
Total No. of Questions	**10**	**8**	**4**	**22**
No. Questions to be answered	**8**	**6**	**2**	**16**

Learning Pedagogy

Chalk and talk, Multimedia projection, e-content, Group discussion, Seminar, Interactive sessions, Tutorials, Assignment, Quiz, LMS

Assessment Tools

Assignments, Seminar, Test papers, End semester examination, Online assignments and tests

SEMESTER 3

Semester III	Code: PG20MT311	MEASURE THEORY AND INTEGRATION	Total Hrs:**90** Hrs/Week:**5**	Credits: 4

Course Objective

- Equip students with the concepts of measurable sets and measurable functions.
- Familiarize classical theorems like Monotone convergence theorem, Dominated convergence theorem, Fatou's lemma etc.
- Apply measure to integrate functions.

Syllabus

Pre-requisites: Algebras of sets, the axiom of choice and infinite direct products, open and closed sets of real numbers
(Chapter 1 - section 4, 5 Chapter 2 - section 5 of Text 1). **(5 hours)**
(No questions shall be asked from this section)

Module 1: Lebesgue measure: introduction, outer measure, measurable sets and Lebesgue measure, & non-measurable sets, measurable functions.
(Chapter 3 - Sec. 1 to 5. of Text 1) **(20 hours)**

Module 2: Lebesgue integral: the Riemann integral,the Lebesgue integral of a bounded function over a set of finite measures, the integral of a non-negative function, the general Lebesgue integral, differentiation of monotone functions.
(Chapter 4 - Sec. 1 – 4. of Text 1, Chapter 5 - Sec. 1. of Text 1) **(20 hours)**

Module 3: Measure and integration: measure spaces, measurable functions, Integration, general convergence theorems, signed measures, the Radon-Nikodym theorem, outer measure and measurability, the extension theorem.
(Chapter 11 - Sec. 1 to 6 of Text 1, Chapter 12 - Sec. 1& 2 of Text 1) **(20 hours)**

Module 4: Convergence: Convergence in measure, almost uniform convergence, measurability in a product space, the product measure and Fubini's theorem.
(Chapter 8 - Sec. 7.1 & 7.2 of Text 2, Chapter 10 - Sec. 10.1& 10.2 of Text 2) **(25 hours)**

Text Books:

1. **H.L. Royden, Real Analysis, Third edition, Prentice Hall of India Private Limited, 1998.**
2. **G. de Barra, Measure Theory and Integration, New Age International (P) Linnilect Publishers.**

References:

1. Halmos P.R, Measure Theory, D.van Nostrand Co1971.
2. P.K. Jain and V.P. Gupta, Lebesgue Measure and Integration, New Age International (P) Ltd., New Delhi, 1986(Reprint 2000).

3. R.G. Bartle, The Elements of Integration, John Wiley & Sons, Inc New York, 1966.
4. Inder K Rana, An Introduction to Measure and Integration, Narosa Publishing House, 1997.

QUESTON PAPER PATTERN

Module	Part A (Wt. : 1) Short Answer	Part B (Wt. : 2) Short Essay	Part C (Wt. : 5) Long Essay	Total
I	3	2	1	**6**
II	3	2	1	**6**
III	2	2	1	**5**
IV	2	2	1	**5**
Total No. of Questions	**10**	**8**	**4**	**22**
No. Questions to be answered	**8**	**6**	**2**	**16**

Course Outcomes

CO No.	Upon completion of this course, the students will be able to:	Knowledge Level
1	Describe fundamental concepts of Measure theory, like measurable sets and functions	K1, K2
2	State some of the classical theorems in measure like Monotone convergence theorem, Dominated convergence theorem, Fatou's Lemma etc.	K1
3	Classify functions using properties of convergence in measure and almost uniform convergence.	K4
4	Develop measure in product space and use it for integrating measurable functions.	K6
Knowledge Levels: K1-Remembering; K2-Understanding; K3-Applying; K4-Analyzing; K5-Evaluating; K6-Creating.		

Learning Pedagogy

Chalk and talk, Multimedia projection, e-content, Group discussion, Seminar, Interactive sessions, Tutorials, Assignment, Quiz, LMS

Assessment Tools

Assignments, Seminar, Test papers, End semester examination, Online assignments and tests

Semester III	Code: PG20MT312	FUNCTIONAL ANALYSIS	Total Hrs:**90**	Credits: **4**
			Hrs/Week:**5**	

Course Objective

- Familiarize students with the basic concepts of functional analysis
- Understand the fundamental theorems of normed spaces and Banach spaces.
- Comprehend and apply the classical theorems like Hahn- Banach theorem, category theorem, uniform boundedness theorem.

Syllabus

Module 1: Vector Space, normed space. Banach space, further properties of normed spaces, finite dimensional normed spaces and subspaces, compactness and finite dimension, linear Operators, bounded and continuous linear operators.
(Chapter 2 - Sections 2.1 – 2.7 of the text) **(20 hours)**

Module 2: Linear functionals, linear operators and functionals on finite dimensional spaces, normed spaces of operators. dual space, inner product space. Hilbert space, further properties of inner product space.
(Chapter 2 - Section 2.8 to 2.10, chapter 3 - Sections 3.1 to 3.2 of the text) **(20 hours)**

Module 3: Orthogonal complements and direct sums, orthonormal sets and sequences, series related to orthonormal sequences and sets, total orthonormal sets and sequences. representation of functionals on Hilbert spaces, Hilbert adjoint operators, Self adjoint, unitary and normal operators.
(Chapter 3 - Sections 3.3 to 3.6, 3.8 to 3.10 of the text) **(25 hours)**

Module 4: Zorn's lemma, Hahn- Banach theorem, Hahn- Banach theorem for complex vector spaces and normed spaces, adjoint operators, reflexive spaces, category theorem(Statement only), uniform boundedness theorem
(Chapter 4 – Sections 4.1 to 4.3, 4.5 to 4.7 of the text) **(25 hours)**

Text Books:

1. **Erwin Kreyszig, Introductory Functional Analysis with applications, John Wiley and sons, New York, 1978.**

References:

1. Simmons, G.F, Introduction to Topology and Modern Analysis, McGraw –Hill, New York 1963.
2. Siddiqi, A.H, Functional Analysis with Applications, Tata McGraw –Hill, New Delhi: 1989
3. Somasundaram. D, Functional Analysis, S.Viswanathan Pvt. Ltd, Madras, 1994
4. Vasistha, A.R and Sharma I.N, Functional analysis, Krishnan Prakasan Media (P) Ltd, Meerut: 1995-96
5. M. Thamban Nair, Functional Analysis, A First Course, Prentice – Hall of India Pvt. Ltd,. 2008
6. Walter Rudin, Functional Analysis, TMH Edition, 1974.

QUESTON PAPER PATTERN

Module	Part A (Wt. : 1) Short Answer	Part B (Wt. : 2) Short Essay	Part C (Wt. : 5) Long Essay	Total
I	2	2	1	**5**
II	3	2	1	**6**
III	3	2	1	**6**
IV	2	2	1	**5**
Total No. of Questions	**10**	**8**	**4**	**22**
No. Questions to be answered	**8**	**6**	**2**	**16**

Course Outcomes

CO No.	Upon completion of this course, the students will be able to:	Knowledge Level
1	Understand and compare the basic concepts of Normed Space, Inner Product Space	K2, K5
2	Explain the concepts of operators and linear functionals.	K3
2	Understand and apply fundamental theorems from the theory of normed and Banach spaces, including the Hahn-Banach theorem and uniform boundedness theorem.	K2, K3
3	Appreciate the role of Zorn's lemma.	K4
Knowledge Levels: K1-Remembering; K2-Understanding; K3-Applying; K4-Analyzing; K5-Evaluating; K6-Creating.		

Learning Pedagogy

Chalk and talk, Multimedia projection, e-content, Group discussion, Seminar, Interactive sessions, Tutorials, Assignment, Quiz, LMS

Assessment Tools

Assignments, Seminar, Test papers, End semester examination, Online assignments and tests

Semester III	Code: PG20MT313	DIFFERENTIAL GEOMETRY	Total Hrs:**90** Hrs/Week:**5**	Credits: **4**

Course Objective

- Elaborate study of geometry in terms of calculus
- Recognize the concepts of curves and surfaces which are almost essential in most Branches of mathematics
- Learn the concept of gauss map, geodesics, parallel transport, Weingarten map,

Syllabus

Module 1: Graphs and level sets, vector fields, the tangent space, surfaces, vector fields on surfaces, orientation.
(Chapters 1 to 5 of the text) **(15 hours)**

Module 2: The Gauss map, geodesics, Parallel transport,
(Chapters 6, 7 & 8 of the text) **(20 hours)**

Module 3: The Weingarten map, curvature of plane curves, Arc length and line integrals
(Chapters 9, 10 & 11 of the text) **(25 hours)**

Module 4: Curvature of surfaces and Parametrized surfaces.
(Chapters 12, 14 of the text) **(30 hours)**

Text Books:

1. **John A.Thorpe, Elementary Topics in Differential Geometry, Springer-Verlag 1979.**

References:

1. Serge Lang, Differential Manifolds 1972.
2. I.M. Siger, J.A Thorpe, Lecture notes on Elementary topology and Geometry, Springer – Verlag, 1967.
3. S. Sternberg, Lectures on Differential Geometry, Prentice-Hall, 1964.
4. M. DoCarmo, Differential Geometry of curves and surfaces, 2016.

QUESTON PAPER PATTERN

Module	Part A (Wt. : 1) Short Answer	Part B (Wt. : 2) Short Essay	Part C (Wt. : 5) Long Essay	Total
I	3	2	1	**6**
II	3	2	1	**6**
III	2	2	1	**5**
IV	2	2	1	**5**
Total No. of Questions	**10**	**8**	**4**	**22**
No. Questions to be answered	**8**	**6**	**2**	**16**

Course Outcomes

CO No.	Upon completion of this course, the students will be able to:	Knowledge Level
1	Develop sound knowledge in the basic concepts in geometry of curves and surfaces in Euclidean space.	K3
2	Explain the concept of Graphs, Level sets, Vector fields.	K3
3	Analyze Surfaces and Vector field on surfaces	K4
4	Appreciate the concepts of gauss map, geodesics, parallel transport, Weingarten map, curvature of plane curves and surface	K4, K5
Knowledge Levels: K1-Remembering; K2-Understanding; K3-Applying; K4-Analyzing; K5-Evaluating; K6-Creating.		

Learning Pedagogy

Chalk and talk, Multimedia projection, e-content, Group discussion, Seminar, Interactive sessions, Tutorials, Assignment, Quiz, LMS

Assessment Tools

Assignments, Seminar, Test papers, End semester examination, Online assignments and tests

Semester III	Code: PG20MT314	PARTIAL DIFFERENTIAL EQUATIONS	Total Hrs:**90** Hrs/Week:**5**	Credits: **4**

Course Objective

- To equip students with the concepts of partial differential equations and how to solve linear and non-linear PDE using different methods.
- Classify PDEs, apply analytical methods and physically interpret the solutions.
- Analyse the two dimensional Laplace Equation and the relation of the Logarithmic potential to the Theory of Functions.

Syllabus

Module 1: Methods of solutions of dx/P = dy/Q = dz/R. Orthogonal trajectories of a system of curves on a surface. Pfaffian differential forms and equations. Solution of Pfaffian differential equations in three variables, Partial differential equations. Origins of first order partial differential equation.
(Chapter 1- Sections 1.3-1.6, Chapter 2- Sections 2.1, 2.2) (20 hours)

Module 2: Linear equations of first order. Integral surfaces passing through a given curve. Surfaces orthogonal to a given system of surfaces. Nonlinear partial differential equation of the first order . Compatible systems of first order equations . Charpits Method. Special types of first order equations. Solutions satisfying given conditions.
(**Chapter 2 - Sections 2.4-2.7, 2.9-2.12**) **(25 hours)**

Module 3: Jacobi' s method The origin of second order equations. Linear partial differential equations with constant coefficients. Equations with variable coefficients.
(Chapter 2-Sections 2.13, Chapter 3-Sections 3.1, 3.4, 3.5) (20 hours)

Module 4: Separation of variables. Nonlinear equations of the second order. Elementary solutions of Laplace equation. Families of equipotential surfaces. The two dimensional Laplace Equation, Relation of the Logarithmic potential to the Theory of Functions.
(Chapter 3- 3.9, 3.11. Chapter 4 -Sections 4.2, 4.3, 4.11, 4.12) (25 hours)

Text Books:

1. **Ian Sneddon, Elements of Partial Differential Equations, Mc Graw Hill Book Company, 1957.**

References:

1. Phoolan Prasad and Renuka Ravindran, Partial Differential Equations, New Age International, 2011.
2. K Sankara Rao, Introduction to Partial Differential Equations, Prentice Hall of India, 2011
3. E T Copson, Partial Differential Equations, Cambridge University Press, 1975.

Course Outcomes

CO No.	Upon completion of this course, the students will be able to:	Knowledge Level
1	Recognise and restate the basic properties of partial differential equations (PDEs) and boundary value problems.	K1, K2
2	Apply a range of techniques to evaluate the solutions of standard partial differential equations.	K3,K5
3	Gain a clear insight to distinguish and analyse the properties of parabolic, hyperbolic and elliptic equations	K2, K4
4	Examine the solutions of Laplace Equations and achieve the capacity to design and evaluate physical phenomena using PDEs..	K1,K4,K6
Knowledge Levels: K1-Remembering; K2-Understanding; K3-Applying; K4-Analyzing; K5-Evaluating; K6-Creating.		

QUESTON PAPER PATTERN

Module	Part A (Wt. : 1) Short Answer	Part B (Wt. : 2) Short Essay	Part C (Wt. : 5) Long Essay	Total
I	2	2	1	**5**
II	3	2	1	**6**
III	3	2	1	**6**
IV	2	2	1	**5**
Total No. of Questions	**10**	**8**	**4**	**22**
No. Questions to be answered	**8**	**6**	**2**	**16**

Learning Pedagogy

Chalk and talk, Multimedia projection, e-content, Group discussion, Seminar, Interactive sessions, Tutorials, Assignment, Quiz, LMS

Assessment Tools

Assignments, Seminar, Test papers, End semester examination, Online assignments and tests

Semester III	Code: PG20MT315	OPTIMIZATION TECHNIQUES	Total Hrs:**90** Hrs/Week:**5**	Credits: **4**

Course Objective

- To familiarise the student in the domain of linear and nonlinear programming.
- To gain sufficient tools for solving programming problems
- Earn knowledge and skills of the theory of games.
- To analyse and evaluate fundamentals of networks and its applications.

Syllabus

Module 1: INTEGER PROGRAMMING

I.L.P in two dimensional space – General I.L.P. and M.I.L.P problems – cutting planes – remarks on cutting plane methods – branch and bound method – examples – general description – the 0 – 1 variable.

(Chapter 6; sections: 6.1 – 6.10 of text – 1) (20 hours)

Module 2: SENSITIVITY ANALYSIS; FLOW AND POTENTIALS IN NETWORKS

Introduction – changes in b_i – changes in c_j – Changes in a_{ij} – introduction of new variables – introduction of new constraints – deletion of variables - deletion of constraints –Goal programming. Graphs- definitions and notation – minimum path problem – spanning tree of minimum length – problem of minimum potential difference – scheduling of sequential activities – maximum flow problem – duality in the maximum flow problem – generalized problem of maximum flow. **(Chapter – 5 & 7 Sections 5.1 to 5.9 & 7.1 to 7.9, 7.15 of text - 1) (25 hours)**

Module 3: THEORY OF GAMES

Matrix (or rectangular) games – problem of games – minimax theorem, saddle point – strategies and pay off – theorems of matrix games – graphical solution – notion of dominance – rectangular game as an L.P. problem.

(Chapter 12; Sections: 12.1 – 12.9 of text – 1) (20 hours)

Module 4: NON- LINEAR PROGRAMMING

Basic concepts – Taylor's series expansion – Fibonacci Search - golden section search – Hooke and Jeeves search algorithm – gradient projection search – Lagrange Multipliers – equality constraint optimization, constrained derivatives – projected gradient methods with equality constraints – nonlinear optimization: Kuhn-Tucker conditions – complimentary Pivot algorithms.

(Chapter 8; Sections: 8.1 – 8.14 of text – 2) (25 hours)

Text Books:

1. **K.V. Mital and C. Mohan, Optimization Methods in Operation Research and Systems Analysis, 3rd edition, 1996.**
2. **Ravindran, Philips and Solberg. Operations Research Principle and Practice, 2nd edition, John Wiley and Sons, 1985.**

References:

1. S.S. Rao, Optimization Theory and Applications, 2nd edition, New Age International Pvt.

2. J.K. Sharma, Operations Research: Theory and Applications, Third edition, Macmillan India Ltd, 2010.
3. Hamdy A. Thaha, Operations Research – An Introduction, 6th edition, Prentice Hall of India Pvt. Ltd.

Course Outcomes

CO No.	Upon completion of this course, the students will be able to:	Knowledge Level
1	Develops a thorough understanding, knowledge and skill to solve problems using different integer linear programming techniques and mixed integer linear programming techniques.	K1, K6
2	Interpret applying sensitivity analysis, Networks Techniques like minimum path problem, maximum flow problem etc.	K2, K3, K4
3	Solve simple games using various techniques	K6
4	Improves skills to analyse a problem and make a mathematical formulation of the problem thus leading to the solution of the problem.	K4, K6
Knowledge Levels: K1-Remembering; K2-Understanding; K3-Applying; K4-Analyzing; K5-Evaluating; K6-Creating.		

QUESTON PAPER PATTERN

Module	Part A (Wt. : 1) Short Answer	Part B (Wt. : 2) Short Essay	Part C (Wt. : 5) Long Essay	Total
I	2	2	1	**5**
II	4	2	1	**7**
III	2	2	1	**5**
IV	2	2	1	**5**
Total No. of Questions	**10**	**8**	**4**	**22**
No. Questions to be answered	**8**	**6**	**2**	**16**

Learning Pedagogy

Chalk and talk, Multimedia projection, e-content, Group discussion, Seminar, Interactive sessions, Tutorials, Assignment, Quiz, LMS

Assessment Tools

Assignments, Seminar, Test papers, End semester examination, Online assignments and tests

SEMESTER 4

Semester IV	Code: PG20MT416	SPECTRAL THEORY	Total Hrs:**90**	Credits: **4**
			Hrs/Week:**5**	

Course Objective

- Familiarize classical theorems like open mapping theorem, closed graph theorem, fixed point theorem.
- Analyse the spectral properties of compact linear operators and their adjoint operators.
- Perceive the concepts of positive operators and projections.

Syllabus

Module 1: Strong and weak convergence, convergence of sequence of operators and functionals, open mapping theorem, closed linear operators, closed graph theorem, Banach fixed point theorem
(Chapter 4 - Sections 4.8, 4.9, 4.12 & 4.13 - Chapter 5 – Section 5.1 of the text) **(25 hours)**

Module 2: Spectral theory in finite dimensional normed space, basic concepts, spectral properties of bounded linear operators, further properties of resolvent and spectrum, use of complex analysis in spectral theory, Banach algebras, further properties of Banach algebras.
(Chapter 7 - Sections 71. to 7.7 of the text) **(25 hours)**

Module 3: Compact linear operators on normed spaces, further properties of compact linear operators, spectral properties of compact linear operators on normed spaces, further spectral properties of compact linear operators, unbounded linear operators and their Hilbert adjoint operators, Hilbert adjoint operators, symmetric and self adjoint linear operators
(Chapter 8 - Sections 8.1 to 8.4 - Chapter 10 Sections 10.1 & 10.2 of the text) **(20 hours)**

Module 4: Spectral properties of bounded self adjoint linear operators, further spectral properties of bounded self adjoint linear operators, positive operators, projection operators, further properties of projections
(Chapter 9 - Sections 9.1, 9.2, 9.3, 9.5, 9.6 of the text) **(20 hours)**

Text Books:

1. **Erwin Kreyszig, Introductory Functional Analysis with applications, John Wiley and sons, New York, 1978.**

References:

1. Simmons, G.F, Introduction to Topology and Modern Analysis, McGraw –Hill, New York 1963.
2. Siddiqi, A.H, Functional Analysis with Applications, Tata McGraw- Hill, New Delhi: 1989
3. Somasundaram. D, Functional Analysis, S.Viswanathan Pvt Ltd, Madras, 1994.
4. Vasistha, A.R and Sharma I.N, Functional analysis, Krishnan Prakasan Media (P) Ltd, Meerut: 1995-96

5. M. Thamban Nair, Functional Analysis, A First Course, Prentice – Hall of India Pvt. Ltd,. 2008
6. Walter Rudin, Functional Analysis, TMH Edition, 1974.

QUESTON PAPER PATTERN

Module	Part A (Wt. : 1) Short Answer	Part B (Wt. : 2) Short Essay	Part C (Wt. : 5) Long Essay	Total
I	2	2	1	**5**
II	3	2	1	**6**
III	3	2	1	**6**
IV	2	2	1	**5**
Total No. of Questions	**10**	**8**	**4**	**22**
No. Questions to be answered	**8**	**6**	**2**	**16**

Learning Pedagogy

CO No.	Upon completion of this course, the students will be able to:	Knowledge Level
1	Distinguish different kinds of convergence of sequence of operators and functionals	K5
2	Explain Banach Algebra and its properties.	K4
3	formulate the spectral mapping theorem.	
4	Apply fundamental properties of bounded and unbounded operators.	K3
5	Develop ideas from the theory of Hilbert spaces to other areas, including Fourier series.	K6
Knowledge Levels: K1-Remembering; K2-Understanding; K3-Applying; K4-Analyzing; K5-Evaluating; K6-Creating.		

Course Outcomes

Chalk and talk, Multimedia projection, e-content, Group discussion, Seminar, Interactive sessions, Tutorials, Assignment, Quiz, LMS

Assessment Tools

Assignments, Seminar, Test papers, End semester examination, Online assignments and tests

Semester IV	Code: PG20MT117	OPERATIONS RESEARCH	Total Hrs:**90** Hrs/Week:**5**	Credits: **4**

Course Objective

- To introduce students to use quantitative methods and techniques for effective decisions-making; model formulation and applications that are used in solving decision problems.
- To familiarize students with Dynamic programming, Queuing Systems, Inventory models

Syllabus

Module 1: Dynamic Programming Introduction , Problem 1- Minimum path problem, Problem 2-Single additive constraint, additively separable return, Problem 3- Single multiplicative constraint, additively separable return, Problem 4-Single additive constraint, multiplicatively separable return, Computational economy in DP , Serial multistage model, Examples of failure, Decomposition , Backward and forward recursion , Systems with more than one constraints, Applications of D.P to continuous systems.
(Chapter 10; Sections 10.1 – 10.12 of text 1) **(25 hours)**

Module 2: Continuous time random processes An example, Formal definitions and theory, the assumptions reconsidered, Steady state probabilities, Birth death processes, The Poisson process.
(Chapter 6 ; Sections 6.11 – 6.16 of text 2) **(20 hours)**

Module 3: Queuing Systems Introduction, An example, General Characteristics, Performance Measures, Relations Among the performance Measures, Markovian Queuing Models, The M/M/1 Model, Limited Queue Capacity, Multiple Servers, An example, Finite Sources.
(Chapter 7; Sections 7.1 –7.11 of text 2) **(20 hours)**

Module 4: Inventory Models: Introduction, The classical Economic Order Quantity, A Numerical example, Sensitivity Analysis, Non Zero lead Time, The EOQ. with shortages allowed The Production Lot size (PLS) models ,The Newsboy Problem (a single period model), A Lot size reorder point model, Variable lead times, The importance of selecting the right model.
(Chapter 8; Sections: 8.1 – 8.14 of text 2) **(25 hours)**

Text Books:

1. **K.V. Mital and C. Mohan, Optimization Methods in Operation Research and Systems Analysis, 3rd edition, New Age International Pvt. Ltd., 1996.**
2. **Ravindran. A, Don T Philips and James J Solberg., Operations Research Principle and Practice, 2nd edition, John Wiley and Sons., 1985.**

References:

1. Fundamentals of Queuing Theory, Donald Gross, Carl M. Harris, 3rd edition, John Wiley and Sons.
2. Hamdy A. Taha, Operations Research – An Introduction, 6th edition, Prentice Hall of India Pvt. Ltd.

3. Man Mohan, P.K. Gupta and Kanti Swarup, Operations Research, Sultan Chand and Sons.

QUESTON PAPER PATTERN

Module	Part A (Wt. : 1) Short Answer	Part B (Wt. : 2) Short Essay	Part C (Wt. : 5) Long Essay	Total
I	3	2	1	**6**
II	3	2	1	**6**
III	2	2	1	**5**
IV	2	2	1	**5**
Total No. of Questions	**10**	**8**	**4**	**22**
No. Questions to be answered	**8**	**6**	**2**	**16**

Course Outcomes

CO No.	Upon completion of this course, the students will be able to:	Knowledge Level
1	Identify the mathematical tools that are needed to solve optimization problems.	K2
2	Differentiate deterministic and probabilistic processes	K4
3	Evaluate various inventory models, queueing models and its applications	K5
4	Devise dynamic programming in various applications	K6
Knowledge Levels: K1-Remembering; K2-Understanding; K3-Applying; K4-Analyzing; K5-Evaluating; K6-Creating.		

Learning Pedagogy

Chalk and talk, Multimedia projection, e-content, Group discussion, Seminar, Interactive sessions, Tutorials, Assignment, Quiz, LMS

Assessment Tools

Assignments, Seminar, Test papers, End semester examination, Online test and assignments

Elective Group A

Semester IV	Code: PG20MT418	PROBABILITY THEORY	Total Hrs:90 Hrs/Week:5	Credits: 3

Course Objective

- To introduce the fundamentals of probability theory and random processes and illustrate these concepts with applications.
- Learn about probability mass functions, probability density functions, moment generating functions and characteristic functions
- Familiarize with Central limit theorem

Syllabus

Module 1: **Introduction to Probability**
Probability space: Sample space, events, sigma fields, sigma field generated by finite number of events, probability measures and its properties, conditional probability, independent events, independent sigma fields.
(Chapter 1) **(15 Hours)**

Module 2: **Random Variables and Expectation**
Random variables: Definition and examples, random vectors, distribution function, discrete and continuous random variables, pmf and pdf of random variables.
Random Vectors : Definition and examples, joint distribution function.
Expectation: Expectation of discrete random variables, expectation of nonnegative random variables, expectation of general random variables, Statements of monotone and dominated convergence theorems for random variables, illustration of expectation of continuous random variables with pdf.
(Chapter 3, 4, Sections 5.1 - 5.3 of Chapter 5, sections 6.1 - 6.4 of Chapter 6) **(30 Hours)**

Module 3: **Expectation and Central Limit Theorem**
Expectation of continuous random variables, Moments of continuous random variables, Conditional Expectation: Independent random variables, Conditional pmf and pdf, conditional expectation using conditional pmf and pdf
(Sections 7.1-7.5 of Chapter 7) **(20 Hours)**

Module 4: **Moment Generating Functions, Characteristic functions and Introduction to Random Walks**
Moment Generating Functions, Characteristic functions: Definition and properties, inversion formulas, continuity theorem. Law of large numbers: Weak and strong law of large numbers, applications. Central limit theorem: central limit theorem, applications Random walks, Simple random walks
(Chapter 8, Sections 9.1 - 9.2 of Chapter 9) **(25 Hours)**

Text Books:

1. **Hoel, P. G., Port, S. C. and Stone, C. J, Introduction to Probability Theory, Houghton Mifflin, 1971.**

References:

1. Dudley, R. M. Real Analysis and Probability. Cambridge, UK: Cambridge University Press, 2002.
2. Feller, William. An Introduction to Probability Theory and its Applications. Vol. I and II. New York, NY: Wiley, 1968-1971.
3. S.C. Gupta and V.K. Kapoor, Fundamentals of Mathematical Statistics, 11th Ed., Sultan Chand & Sons, 2011.
4. V.K. Rohatgi, An Introduction to Probability Theory and Mathematical Statistics, 2nd Ed. Wiley Eastern Ltd., 1986.

QUESTON PAPER PATTERN

Module	Part A (Wt. : 1) Short Answer	Part B (Wt. : 2) Short Essay	Part C (Wt. : 5) Long Essay	Total
I	3	2	0	5
II	2	2	2	8
III	2	2	1	5
IV	3	2	1	3
Total No. of Questions	10	8	4	22
No. Questions to be answered	8	6	2	16

Course Outcomes

CO No.	Upon completion of this course, the students will be able to:	Knowledge Level
1	Write probabilities by applying probability laws and theoretical results	K6
2	Identify an appropriate probability distribution for a given discrete or continuous random variable and use its properties to calculate probabilities	K1, K6
3	Use random variables, distribution functions, probability mass functions, and probability density functions, through calculus and functional transformations, to answer quantitative questions	K4, K5
4	Apply results from Central Limit Theorem to approximate sampling distribution	K3
Knowledge Levels: K1-Remembering; K2-Understanding; K3-Applying; K4-Analyzing; K5-Evaluating; K6-Creating.		

Learning Pedagogy

Chalk and talk, Multimedia projection, e-content, Group discussion, Seminar, Interactive sessions, Tutorials, Assignment, Quiz

Assessment Tools

Assignments, Seminar, Test papers, End semester examination

Semester IV	Code: PG20MT419	CODING THEORY	Total Hrs:**90**	Credits: **3**
			Hrs/Week:**5**	

Course Objective

- Introduce linear codes in terms of generator and parity-check matrices. Discuss coset decomposition and syndrome decoding.
- Introduce cyclic codes in terms of generator and parity-check polynomials. Discuss shift register based encoding and decoding. Define Reed-Solomon (RS) and Bose-Chaudhuri-Hocquenghem (BCH) codes using generator and parity-check polynomials.

Syllabus

Module:-1 Introduction Basic Definitions Weight, Maximum Likelihood decoding Synarome decoding, Perfect Codes, Hamming codes, Sphere packing bound, more general facts.
(chapter 1 & Chapter 2 Sections 2.1, 2.2, 2.3 of the text) (25 hours)

Module:-2 Self dual codes, The Golay codes, A double error correction BCH code and a field of 16 elements.
(Chapter 2 Section 2.4 & Chapter 3 of the text) (20 hours)

Module:- 3 Finite fields
(Chapter 4 of the text) (20 hours)

Module:- 4 Cyclic Codes, BCH codes)
(Chapter 5 & Chapter 7 of the text) (25 hours)

Text Books:

1. **Vera Pless 3rd Edition , Introduction to the theory of error correcting codes, Wiley Inter Science, 1997.**

References:

1. R-Lidi, G. Pliz, Applied Abstract Algebra, Springer Verlag, 1984.
2. J.H.Van Lint, Introduction to Coding Theory, Springer Verlag, 1982.
3. R.E.Blahut, Error- Control Codes, Addison Wesley, 1983.

QUESTON PAPER PATTERN

CO No.	Upon completion of this course, the students will be able to:	Knowledge Level
1	Analyse various error control code properties, error detection and correction	K4
2	Describe various methods of generating and detecting different types of error correcting codes	K2
3	Describe the fundamentals of coding theory	K2
4	Apply properties and algorithms for coding and decoding of linear block codes, cyclic codes.	K3
5	Apply various algorithms and techniques for BCH decoding.	K3
Knowledge Levels: K1-Remembering; K2-Understanding; K3-Applying; K4-Analyzing; K5-Evaluating; K6-Creating.		

Course Outcomes

Module	Part A (Wt. : 1) Short Answer	Part B (Wt. : 2) Short Essay	Part C (Wt. : 5) Long Essay	Total
I	3	3	1	7
II	2	2	1	5
III	3	1	1	5
IV	2	2	1	5
Total No. of Questions	10	8	4	22
No. Questions to be answered	8	6	2	16

Learning Pedagogy

Chalk and talk, Multimedia projection, e-content, Group discussion, Seminar, Interactive sessions, Tutorials, Assignment, Quiz, LMS

Assessment Tools

Assignments, Seminar, Test papers, End semester examination, Online assignments and tests

Semester **IV**	Code: **PG20MT420**	**COMPUTER METHODS**	Total Hrs:**90** / Hrs/Week:**5**	Credits: **3**

Course Objective

- Introduction to programming and programming language Python for the students who have no or very little programming knowledge
- Write small Python programmes
- Solve some mathematical problems applying Python programming

Syllabus

Module 1: Getting started with Python: Introduction to programming, variables, keywords, operators, expressions, statements, conditional execution, logical operators, Boolean expressions, functions, function calls, built-in functions, type conversion functions, math functions, adding new functions, iteration, for & while statements, infinite loops.
(Chapters 1, 2, 3, 4 and 5 of Text 1) **(25 hours)**

Module 2: Python Data Structures: Strings, traversal through a string with a loop, string slices, looping and counting, string comparison, parsing strings, files, opening files, text files and lines, reading files, searching through a file, writing files, lists, traversing a list, list operations, deleting elements, lists and functions, lists and strings, list arguments.
(Chapters 6, 7 and 8 of Text 1) **(20 hours)**

Module 3: Defining Symbols and Symbolic Operations, Working with Expressions, Solving Equations and Plotting Using SymPy, problems on factor finder, summing a series and solving single variable inequalities.
(Chapter 4, Text 2) **(20 hours)**

Module 4: Finding the limit of functions, finding the derivative of functions, higher-order derivatives and finding the maxima and minima and finding the integrals of functions are to be done. in the section programming challenges, the following problems - verify the continuity of a function at a point, area between two curves and finding the length of a curve.
(Chapter 7, Text 2) **(25 hours)**

1. Any distribution of Python 3 software can be used for practical sessions.
2. Instead of assignments, a practical record book should be maintained by the students. At least 15 programmes should be included in this record book.
3. Internal assessment examinations should be conducted as practical lab examinations by the faculty handling the paper.

4. End semester examination should focus on questions including concepts from theory and programming. However, more importance should be given to theory in the end semester examinations as internal examinations will be giving more focus on programming sessions.

Text Books:

1. **Python for Everybody - Exploring Data Using Python 3, Charles R. Severance, Shroff Publishers, 2017.**
2. **Amit Saha, Doing Math with Python, No Starch Press, 2015.**

References:

1. Python Programming Fundamentals, Kent D Lee, Springer, 2014
2. Programming Python, Mark Lutz, O'Reilly, 2011
3. Vernon L. Ceder, The Quick Python Book, Second Edition, Manning, 2009
4. NumPy Reference Release 1.12.0, Written by the NumPy community. (available for free download at https://docs.scipy.org/doc/numpy-dev/numpy-ref.pdf)
5. A primer on scientific programming with python, 3rd edition, Hans Petter Langtangen, Springer

QUESTON PAPER PATTERN

Module	Part A (Wt. : 1) Short Answer	Part B (Wt. : 2) Short Essay	Part C (Wt. : 5) Long Essay	Total
I	3	2	1	6
II	2	2	1	5
III	3	2	1	6
IV	2	2	1	5
Total No. of Questions	10	8	4	22
No. Questions to be answered	8	6	2	16

Course Outcomes

CO No.	Upon completion of this course, the students will be able to:	Knowledge Level
1	Describe the core syntax and semantics of Python programming language.	K2
2	Interpret the process of structuring the data using lists	K3
3	Experiment with small meaningful Python programs	K4
4	Facilitate Python programming for solving problems in Mathematics.	K6
Knowledge Levels: K1-Remembering; K2-Understanding; K3-Applying; K4-Analyzing; K5-Evaluating; K6-Creating.		

Learning Pedagogy

Chalk and talk, Multimedia projection, e-content, Group discussion, Seminar, Interactive sessions, Tutorials, Assignment, Quiz, LMS

Assessment Tools

Assignments, Seminar, Test papers, End semester examination, Online assignments and tests

Elective Group B

Semester IV	Code: PG20MT421	COMBINATORICS	Total Hrs:**90**	Credits: **3**
			Hrs/Week:**5**	

Course Objective

- To improve mathematical reasoning and problem solving skills using the various counting principles.
- To find integer solutions and shortest routes using the principle of inclusion and exclusion.
- To find recurrence relations for sequences and apply generating function methods to solve combinatorial questions.

Syllabus

Module 1: **Permutations and Combinations**
Two basic counting principles, Permutations, Circular permutations, Combinations, The injection and bijection principles, Arrangements and selection with repetitions, Distribution problems
(Chapter I of the text) **(20 hours)**

Module 2: **The Pigeonhole Principle and Ramsey Numbers**
Introduction, The pigeonhole principle, More examples, Ramsey type problems and Ramsey numbers, Bounds for Ramsey numbers
(Chapter 3 of the text) **(20 hours)**

Module 3: **Principle of Inclusion and Exclusion**
Introduction, The principle, A generalization, Integer solutions and shortest routes, Surjective mappings and Sterling numbers of the second kind, Derangements and a generalization, The Sieve of Eratosthenes and Euler j –function.
(Chapter -4 Sections 4.1 to 4.7 of the text) **(25 hours)**

Module 4: **Generating Functions**
Ordinary generating functions, Some modelling problems, Partitions of integer, Exponential generating functions
Recurrence Relations
Introduction, Two examples, Linear homogeneous recurrence relations, General linear recurrence relations, Two applications
(Chapter 5, 6 Sections 6.1 to 6.5) **(25 hours)**

Text Books:

1. **Chen Chuan -Chong, Koh Khee Meng, Principles and Techniques in Combinatorics, World Scientific,1999.**

References:

1. V Krishnamoorthy, Combinatorics theory and applications, E. Hoewood, 1986

2. Hall, Jr, Combinatorial Theory, Wiley- Interscience, 1998.
3. Brualdi, R A, Introductory Combinatorics, Prentice Hall,1992.

QUESTON PAPER PATTERN

Module	Part A (Wt. : 1) Short Answer	Part B (Wt. : 2) Short Essay	Part C (Wt. : 5) Long Essay	Total
I	2	2	1	5
II	3	3	1	7
III	3	2	1	6
IV	2	1	1	4
Total No. of Questions	10	8	4	22
No. Questions to be answered	8	6	2	16

Course Outcomes

CO No.	Upon completion of this course, the students will be able to:	Knowledge Level
1	Develop mathematical thinking and logical skills	K3, K6
2	State and explain the basic counting principles, apply permutations and combinations in a wide variety of situations.	K1,K2,K3
3	Solve advanced counting problems using the Pigeonhole Principle and the Principle of Inclusion Exclusion.	K3,K6
4	Evaluate generating functions and calculate recurrence relations to solve counting problems.	K3, K4,K5,K6
Knowledge Levels: K1-Remembering; K2-Understanding; K3-Applying; K4-Analyzing; K5-Evaluating; K6-Creating.		

Learning Pedagogy

Chalk and talk, Multimedia projection, e-content, Group discussion, Seminar, Interactive sessions, Tutorials, Assignment, Quiz, LMS

Assessment Tools

Assignments, Seminar, Test papers, End semester examination, Online assignments and tests

Semester IV	Code: PG20MT422	ANALYTIC NUMBER THEORY	Total Hrs:**90**	Credits: **3**
			Hrs/Week:**5**	

Course Objective

- To help students develop an understanding of basic properties of arithmetic functions, summation techniques, average orders of arithmetical functions, prime number theorem and the distribution of primes.

Syllabus

- Understand the basic congruence theorems like Fermat's theorem, lagrange's theorem.
- The concepts of existence and non-existence of Primitive roots and to develop generating functions for finding partitions.

Module 1: **Arithmetic Functions Dirichlet Multiplication and Averages of Arithmetical functions**

Introduction to Chapter1 of the text, the Mobius function $\mu(n)$, the Euler totient function $\phi(n)$, a relation connecting $\mu(n)$ and $\phi(n)$, the Dirichlet product of arithmetical functions, Dirichlet inverses and Mobius inversion formula, the Mangoldt function $\Lambda(n)$, multiplicative e functions and Dirichlet multiplication, the inverse of completely multiplicative functions, the Liovillie's function , the divisor function $\sigma_\alpha(n)$, generalized convolutions, formal power series, the Bell series of an arithmetical function, Bell series and Dirichlet multiplication. Introduction to Chapter2 of the text, the big oh notation, asymptotic equality of functions, Euler's summation formula, some elementary asymptotic formulas, the average order of $d(n)$, The average order of the divisor function $\sigma_\alpha(n)$, average order of $\phi(n)$, an application of distribution of lattice points visible from the origin, average order of $\mu(n)$ and $\Lambda(n)$,the partial sums of a Dirichlet product, application to $\mu(n)$ and $\Lambda(n)$.
(Chapter 2 sections 2.1 to 2.17 and Chapter 3 sections 3.1 to 3.11 of the text) **(30 hours)**

Module 2: **Some Elementary Theorems on the Distribution of Prime Numbers**

Introduction to Chapter 4, Chebyshev's functions and , relation connecting $\psi(x)$ and $J(x)$, some equivalent forms of prime number theorem, inequalities of $\pi(n)$ and $p(n)$, Shapiro's Tauberian theorem, applications of Shapiro's theorem, an asymptotic formula for the partial sum $\sum_{p\le x}\left(\frac{1}{p}\right)$.
(Chapter 4 sections 4.1 to 4.8 of the text) **(15 hours)**

Module 3: **Congruences**

Definition and basic properties of congruences, residue classes and complete residue systems, linear congruences , reduced residue systems and Euler – Fermat theorem, Polynomial congruences modulo , Lagrange's theorem, applications of Lagrange's theorem, simultaneous linear congruences, the Chinese remainder theorem, applications of Chinese remainder theorem, polynomial congruences with prime power moduli

(Chapter 5 sections 5.1 to 5.9 of the text) (30 hours)

Module 4: **Primitive roots and partitions**

The exponent of a number mod m. Primitive roots, Primitive roots and reduced systems, The non existence of Primitive roots mod 2_a for a ³3, The existence of Primitive roots mod p for odd primes p, Primitive roots and quadratic residues. Partitions – Introduction, Geometric representation of partitions, Generating functions for partitions, Euler's pentagonal-number theorem.

(Chapter 10 sections 10.1 to 10.5 & Chapter 14 sections 14.1 to 14.4 of the text) (15 hours)

Text Books:

1. **Tom M Apostol, Introduction to Analytic Number Theory, Springer International Student Edition, Narosa Publishing House, 1976.**

References:

1. Hardy G.H and Wright E.M , Introduction to the Theory of numbers, Oxford, 1981
2. Leveque W.J, Topics in Number Theory, Addison Wesley, 1961.
3. J.P Serre, A Course in Arithmetic, GTM Vol. 7, Springer-Verlag, 1973

QUESTON PAPER PATTERN

Module	Part A (Wt. : 1) Short Answer	Part B (Wt. : 2) Short Essay	Part C (Wt. : 5) Long Essay	Total
I	3	3	1	**7**
II	3	1	1	**5**
III	2	3	1	**6**
IV	2	1	1	**4**
Total No. of Questions	**10**	**8**	**4**	**22**
No. Questions to be answered	**8**	**6**	**2**	**16**

Course Outcomes

CO No.	Upon completion of this course, the students will be able to:	Knowledge Level
1	Master the basic methods of analytic number theory including Abel's summation and Mobius inversion.	K2, K3
2	Develop an understanding of arithmetic functions and their utility in the analytic theory of numbers including the distribution of primes.	K3
3	Understand the basic theories in number theory including Fermat's and Chinese remainder theorem.	K1
4	Analyse the importance of primitive roots and partitions of integers in analytic number theory and to create generating functions.	K4,K6
Knowledge Levels: K1-Remembering; K2-Understanding; K3-Applying; K4-Analyzing; K5-Evaluating; K6-Creating.		

Learning Pedagogy

Chalk and talk, Multimedia projection, e-content, Group discussion, Seminar, Interactive sessions, Tutorials, Assignment, Quiz, LMS

Assessment Tools

Assignments, Seminar, Test papers, End semester examination, Online assignments and tests

Semester IV	Code: PG20MT423	MATHEMATICAL ECONOMICS	Total Hrs:**90**	Credits: **3**
			Hrs/Week:**5**	

Course Objective

- Learn the mathematical skills necessary to study economics
- Use of mathematical techniques in economic analysis

Syllabus

Module 1: **The theory of consumer behaviour**- Maximization of utility, Indifference curve approach, Marginal rate of substitution, Consumer's equilibrium, Demand curve, Relative preference theory of demand, Numerical problems related to these theory part.
(Chapter – 13 .Sections 13.1, 13.2, 13.3, 13.4, 13.5, 13.6 & 13.13 of text - 1) **(20 hours)**

Module 2: **The production function**:- Meaning and nature of production function, The law of variable proportion, Isoquants, Marginal technical rate of substitution, Producer's equilibrium, expansion path, The elasticity of substitution, Ridge lines and economic region of production,
Euler's theorem, Cobb Douglas production function, The CES Production function, Numerical problems related to these theory parts.
(Chapter – 14. Sections 14.1, 14.2, 14.3, 14.4, 14.5, 14.6, 14.7, 14.8, 14.9, 14.10 & 14.11 of text - 1) **(30 hours)**

Module 3: **Input – Output Analysis**:- Meaning of input – output, main features of analysis, Assumptions, Leontief's static and dynamic model, limations, Importance and Applications of analysis, Numerical problems related to these theory parts. **(Chapter – 15. Section 15.1, 15.2, 15.3, 15.4, 15.5,15.6, 15.7, 15.8 & 15.9 of text - 1)** **(20 hours)**

Module 4: **Difference equations** –Introduction, Definition and Classification of Difference equations, Linear Difference equations, Solution of Difference equations, Linear First-Order Difference equations with constant coefficients, Behaviour of the solution sequence, Equilibrium and Stability, Applications of Difference equations in Economic Models, The Harrod Model, The General Cobweb Model, Consumption Model, Income – Consumption – Investment Model. **(Chapter 6 Sections 6.1 to 6.5 of text 2)** **(20 hours)**

Text Books:

1. **Singh S.P, Anil K.Parashar, Singh H.P, Econometrics and Mathematical Economics, S. Chand & Company, 2002.**
2. **Jean E. Weber, Mathematical Analysis Business and Economic Applications, Fourth edition, Harper & Row publishers, New York, 1982.**

References:

1. Allen R.G.D, Mathematical Economics, 1959.

2. Alpha C Chiang, Fundamental methods of Mathematical Economics.
3. Koutsoyiannis. A, Modern Microeconomics, Macmillen.
4. Samuelson. P.A, Foundation of Economic Analysis.
5. Josef Hadar, Mathematical theory of economic behaviour, Addison-Wesley

QUESTON PAPER PATTERN

Module	Part A (Wt. : 1) Short Answer	Part B (Wt. : 2) Short Essay	Part C (Wt. : 5) Long Essay	Total
I	3	2	1	**6**
II	4	3	1	**8**
III	2	2	1	**5**
IV	1	1	1	**3**
Total No. of Questions	**10**	**8**	**4**	**22**
No. Questions to be answered	**8**	**6**	**2**	**16**

Course Outcomes

CO No.	Upon completion of this course, the students will be able to:	Knowledge Level
1	Establish deep insight into the importance of mathematical methods in economics and apply a range of mathematical techniques to economic problems	K3
2	Infer clearly the meaning, nature and characteristics of production function.	K2
3	Identify the meaning and main features of input – output analysis and apply them in solving problems from various disciplines.	K1, K6
4	Acquire the skills to analyse difference equations and implement them in solving Economic models	K5, K6
Knowledge Levels: K1-Remembering; K2-Understanding; K3-Applying; K4-Analyzing; K5-Evaluating; K6-Creating.		

Learning Pedagogy

Chalk and talk, Multimedia projection, e-content, Group discussion, Seminar, Interactive sessions, Tutorials, Assignment, Quiz, LMS

Assessment Tools

Assignments, Seminar, Test papers, End semester examination, Online assignments and tests

Elective Group C

Semester IV	Code: PG20MT424	ADVANCED COMPLEX ANALYSIS	Total Hrs:**90**	Credits: **3**
			Hrs/Week:**5**	

Course Objective

- To gain a knowledge of topological concepts in the context of complex analysis
- To develop an analytic function as a power series
- To learn the concept of complex logarithms

Syllabus

Module 1: Elementary theory of power series: sequences, series, uniform convergence, power series, Abel's limit theorem. Power series expansions: Weierstrass' theorem, the Taylor's series, the Laurent's series, Partial fractions and factorisation: partial fractions, infinite products, canonical products, the gamma functions. **(Chapter 2, Section 2 - Chapter 5, Sections 1, 2.1 to 2.4 of the text) (25 hours)**

Module 2: Entire functions: Jenson's formula, Hadamard's theorem (without proof) the Riemann zeta function: the product development, extension of x to the whole plane, the functional equation, the zeros of zeta function.
Normal families: Equi continuity, normality and compactness, Arzela's theorem (without proof)
(Chapter 5 - Sections 3, 4, 5.1,5.2, and 5.3 of the text) (25 hours)

Module 3: The Riemann mapping theorem: statement and proof, boundary behavior, use of reflection principle, analytic arcs. Conformal mappings of polygons: the behavior of an angle, the Schwarz-Christoffel formulaI (Statement only).
A closer look at harmonic functions: functions with mean value property, Harnack's principle. The Dirichlet problem: sub harmonic functions, solution of Dirichlet problem (statement only)
(Chapter 6 Section 1, 2.1, 2.2, 3, 4.1 & 4.2 of the text) (20 hours)

Module 4: Elliptic functions: simply periodic functions, representation of exponentials, the Fourier development, functions of finite order
Doubly periodic functions: The period module, unimodular transformations, the canonical basis, general properties of elliptic functions.
The Weirstrass theory: the Weierstrass function, the functions x (y) and s (y), the differential equation. Analytic continuation: the Weierstrass theorem, Germs and Sheaves, sections and Riemann surfaces, analytic continuation along arcs, homotopic curves.
(Chapter 7 Sections 1, 2, 3.1, 3.2, 3.3, Chapter 8 Sections 1.1 to 1.5 of the text) (20 hours)

Text Books:

1. **Lars V. Ahlfors, Complex Analysis, Third edition, McGraw Hill Internationals,1998.**

References:

1. Chaudhary. B, The elements of Complex Analysis, Wiley Eastern.
2. Cartan. H (1973), Elementary theory of Analytic functions of one or several variable, Addison Wesley.
3. Conway .J.B, Functions of one Complex variable, Narosa publishing.
4. Lang. S, Complex Analysis, Springer.
5. H.A. Priestly, Introduction to Complex Analysis, Clarendon press, Oxford, 1990.

QUESTON PAPER PATTERN

Module	Part A (Wt. : 1) Short Answer	Part B (Wt. : 2) Short Essay	Part C (Wt. : 5) Long Essay	Total
I	3	2	1	6
II	4	3	1	8
III	2	2	1	5
IV	1	1	1	3
Total No. of Questions	10	8	4	22
No. Questions to be answered	8	6	2	16

Course Outcomes

CO No.	Upon completion of this course, the students will be able to:	Knowledge Level
1	Apply complex numbers in various representations, define fundamental topological concepts in the context of the complex plane, and define and calculate limits and derivatives of functions of a complex variable.	K1,K3,K4
2	Apply fundamental results, including: Cauchy's Theorem and Cauchy's Integral Formula, the Fundamental Theorem of Algebra, Morera's Theorem and Liouville's Theorem.	K3
3	Co-relate analytic functions as power series on their domains and verify that they are well defined.	K4
4	Define a branch of the complex logarithm, classify singularities and find Laurent series for meromorphic functions. Develop examples to explain concepts	K2,K6
Knowledge Levels: K1-Remembering; K2-Understanding; K3-Applying; K4-Analyzing; K5-Evaluating; K6-Creating.		

Learning Pedagogy

Chalk and talk, Multimedia projection, e-content, Group discussion, Seminar, Interactive sessions, Tutorials, Assignment, Quiz, LMS

Assessment Tools

Assignments, Seminar, Test papers, End semester examination, Online assignments and tests

Semester IV	Code: PG20MT425	COMMUTATIVE ALGEBRA	Total Hrs:**90** Hrs/Week:**5**	Credits: **3**

Course Objective

- To understand the basics of commutative ring theory
- To develop a clear understanding of Noetherian Rings and spaces

Syllabus

Module 1: **The Algebra-Geometry Lexicon – Hilbert's Nullstellensatz**
Maximal ideals, Jacobson Rings, Coordinate Rings, Simple problems.
(Chapter1 Sections 1.1, 1.2 & 1.3 of the text) **(25 hours)**

Module 2: **Noetherian and Artinian Rings.**
The Noether and Artin Properties for Rings and Modules, Noetherian Rings and Modules, Simple problems
(Chapter2 Sections 2.1 & 2.2, of the text) **(20 hours)**

Module 3: **The Zariski Topology**
Affine Varieties, Spectra, Noetherian and Irreducible Spaces, Simple problems.
(Chapter 3 Sections 3.1, 3.2 & 3.3 of the text) **(25 hours)**

Module 4: **A Summary of the Lexicon**
True Geometry: Affine Varieties, Abstract Geometry : Spectra , Simple problems
(Chapter 4 Sections 4.1 & 4.2, of the text) **(20 hours)**

Text Books:

1. **Gregor Kemper, A Course in Commutative Algebra, Springer, 2011.**

References:

1. William W. Adams, Phillippe Loustaunau, An Introduction to Grobner bases,
2. Graduate Studies in Mathematics 3, American Mathematical Society, 1994, [117]
3. Michael F Attiyah, Ian Grant Macdonald, Introduction to Commutative Algebra, Addison- Wesley, Reading, 1969[174]
4. Nicolas Bourbaki, General Topology, Chapters 1 – 4, Springer, Berlin, 1993, [117, 118, 161]

QUESTON PAPER PATTERN

Module	Part A (Wt. : 1) Short Answer	Part B (Wt. : 2) Short Essay	Part C (Wt. : 5) Long Essay	Total
I	3	2	1	6
II	2	2	1	5
III	3	2	1	6
IV	2	2	1	5
Total No. of Questions	10	8	4	22
No. Questions to be answered	8	6	2	16

Course Outcomes

CO No.	Upon completion of this course, the students will be able to:	Knowledge Level
1	Identify Maximal ideals , Jacobson Rings and Coordinate Rings	K2
2	Distinguish Noether and Artin Properties for Rings and Modules	K2
3	Explain affine Varieties and Spectra	K4
4	Describe Noetherian and Irreducible Spaces	K2
5	Recognize of the Lexicon	K1
Knowledge Levels: K1-Remembering; K2-Understanding; K3-Applying; K4-Analyzing; K5-Evaluating; K6-Creating.		

Learning Pedagogy

Chalk and talk, Multimedia projection, e-content, Group discussion, Seminar, Interactive sessions, Tutorials, Assignment, Quiz, LMS

Assessment Tools

Assignments, Seminar, Test papers, End semester examination, Online assignments and tests

Semester IV	Code: PG20MT426	**ALGORITHMIC GRAPH THEORY**	Total Hrs:**90**	Credits: **3**
			Hrs/Week:**5**	

Course Objective

- Study of properties of graphs and networks from an algorithmic perspective.
- Understand the basic properties of graphs that can be used to design efficient algorithms

Syllabus

Module 1: Introduction to Graphs and Algorithms

Introduction to graphs. isomorphic graphs. subgraphs, degree sequences. connected graphs. cut vertices and blocks. special graphs. digraphs. algorithmic complexity. Search algorithms, sorting algorithms, greedy algorithms, representing graphs in a computer.

(Chapter 1 Sections 1.1 to 1.9, Chapter 2 Sections 2.1, 2.2 , 2.3, 2.5 and 2.6 of the text) (24 hours)

Module 2: Trees, paths and distances

Properties of trees, rooted trees. Depth-first search,. breadth – first search, . the minimum spanning tree problem. Distance in a graphs, distance in weighted graphs, centre and median of a graph. Activity digraphs and critical paths.

(Chapter 3 sections 3.1 to 3.3.3.4 and 3.5 , Chapter 4 sections 4.1 to 4.4 of the text) (22 hours)

Module 3: Networks

An introduction to networks. the max-flow min-cut theorem. the max-flow min-cut algorithm . Connectivity and edge connectivity . Mengers theorem.

(Chapter 5 sections 5.1 , 5.2 , 5.3 and 5.5 of the text) (22 hours)

Module 4: Matchings and Factorizations

An introduction to matchings . maximum matchings in a bipartite graph,. Factorizations. Block Designs.

(Chapter 6 sections 6.1 , 6.2 , 6.4 and 6.5 of the text) (22 hours)

Text Books:

1. **Hoel, P. G., Port, S. C. and Stone, C. J, Introduction to Probability Theory, Houghton Mifflin, 1971.**

References:

1. Alan Gibbons, Algorithmic Graph Theory, Cambridge University Press, 1985
2. Mchugh. J.A, Algorithmic Graph Theory, Prentice-Hall, 1990
3. Golumbic. M, Algorithmic Graph Theory and Perfect Graphs, Academic press.

QUESTON PAPER PATTERN

Module	Part A (Wt. : 1) Short Answer	Part B (Wt. : 2) Short Essay	Part C (Wt. : 5) Long Essay	Total
I	3	2	1	6
II	3	2	1	6
III	2	2	1	5
IV	2	2	1	5
Total No. of Questions	10	8	4	22
No. Questions to be answered	8	6	2	16

Course Outcomes

CO No.	Upon completion of this course, the students will be able to:	Knowledge Level
1	Understand the basics of Algorithm Analysis and Design.	K2
2	Illustrate the complexity of Algorithms.	K4
3	Discriminate BFS and DFS search on trees.	K5
4	Develop algorithms on networks. Explain matchings and factorization	K3, K4
Knowledge Levels: K1-Remembering; K2-Understanding; K3-Applying; K4-Analyzing; K5-Evaluating; K6-Creating.		

Learning Pedagogy

Chalk and talk, Multimedia projection, e-content, Group discussion, Seminar, Interactive sessions, Tutorials, Assignment, Quiz, LMS

Assessment Tools

Assignments, Seminar, Test papers, End semester examination, Online assignments and tests

Elective Group D

Semester **IV**	Code: **PG20MT427**	**LIE ALGEBRAS**	Total Hrs:**90** Hrs/Week:**5**	Credits: **3**

Course Objective

- To familiarize various techniques for working with Lie algebras

Syllabus

Module 1: **Basic Concepts**
Definition and first examples, Ideals and homomorphisms, Solvable and nilpotent Lie Algebras.
(Chapter I Sections 1, 2, & 3 of the text) **(25 hours)**

Module 2: **Semi simple Lie Algebras**
Theorems of Lie and Cartan, Killing form, Complete reducibility of representations.
(Chapter II Sections 4, 5, & 6 of the text) **(20 hours)**

Module 3: **Root Systems**
Axiomatics, Simple roots and Weyl group, Classification.(proof of Classification theorem excluded)
(Chapter III Sections 9, 10 & 11 of the text) **(25 hours)**

Module 4: **Isomorphism and Conjugacy Theorems**
Isomorphism theorem, Cartan Algebras, Conjugacy theorems
(Chapter IV Sections 14, 15, & 16 – 16.1 to 16.3 of the text) **(20 hours)**

Text Books:

1. **James E. Humphreys, Introduction to Lie Algebras and Representation Theory, Springer, 1972.**

References:

1. J.G.F. Belinfante and B. Kolman, Asurvey of Lie Groups and Lie Algebras with computational methods and Applications, .Philadelphia : SIAM, 1972.
2. N. Jacobson, Lie Algebras, New York – London, Wiley interscience, 1962.
3. H. Samuelson, Notes on Lie Algebras, Van Nostrand Reinhold Mathematical studies No. 23, New York: Van Nostrand Reinhold, 1969.

QUESTON PAPER PATTERN

Module	Part A (Wt. : 1) Short Answer	Part B (Wt. : 2) Short Essay	Part C (Wt. : 5) Long Essay	Total
I	3	2	1	6
II	3	2	1	6
III	2	3	1	6
IV	2	1	1	4
Total No. of Questions	10	8	4	22
No. Questions to be answered	8	6	2	16

Course Outcomes

CO No.	Upon completion of this course, the students will be able to:	Knowledge Level
1	Identify and summarize various techniques for working with Lie algebras	K2, K5
2	Gain an understanding of some major classification result	K2
Knowledge Levels: K1-Remembering; K2-Understanding; K3-Applying; K4-Analyzing; K5-Evaluating; K6-Creating.		

Learning Pedagogy

Chalk and talk, Multimedia projection, e-content, Group discussion, Seminar, Interactive sessions, Tutorials, Assignment, Quiz, LMS

Assessment Tools

Assignments, Seminar, Test papers, End semester examination, Online assignments and tests

Semester **IV**	Code: **PG20MT428**	**ALGEBRAIC TOPOLOGY**	Total Hrs:**90** / Hrs/Week:**5**	Credits: **3**

Course Objective

- To familiarize students with homotopy theory and homology theory
- To make an elaborate study on the following concepts; connectedness and geometric complexes, simplicial homology groups, simplicial approximation, fundamental group and covering spaces.

Syllabus

Module 1: Geometric complexes and Polyhedra-Introduction-Examples-Orientations of geometric complexes-Chains-Cycles-boundaries and Homology groups-Examples of Homology -The structure of Homology groups-The Euler-Poincare Theorem- Pseudomanifolds and the Homology groups of S.

(25 Hours)

Module 2: Simplicial approximations-Induced homomorphisms on the Homology groups-The Brouwer fixed point Theorem and related results.

(20 Hours)

Module 3: The Fundamental group-The covering homotopy property for S_-Examples of fundamental groups-the relation between $H_1(K)$ and $H_1(|K|)$.

(25 Hours)

Module 4: Covering spaces -Definition and some examples-Basic properties of covering spaces- Classification of covering spaces-Universal covering spaces.

(20 Hours)

Text Books:

1. **Fred H.Croom-Basic concepts of Algebraic Topology (Springer verlag) Chapters 1-5 (All sections and Theorems)**

References:

1. B.K.Lahiri-A first Course in Algebraic Topology (Second Edition)-Narosa Publications- ISBN 81-7319-635-4
2. Glen E.Bredon-Topology and Geometry (Springer)- ISBN 81-8128-266-3.
3. Joseph J.Rotman-An Introduction to Algebraic Topology (Springer) –ISBN 81-8128- 179-9.

QUESTON PAPER PATTERN

Module	Part A (Wt. : 1) Short Answer	Part B (Wt. : 2) Short Essay	Part C (Wt. : 5) Long Essay	Total
I	3	2	1	6
II	2	2	1	5
III	3	2	1	6
IV	2	2	1	5
Total No. of Questions	10	8	4	22
No. Questions to be answered	8	6	2	16

Course Outcomes

CO No.	Upon completion of this course, the students will be able to:	Knowledge Level
1	Validate and connect topological concepts with algebraic concepts.	K6
2	Explain the concepts of connectedness and geometric complexes, simplicial homology groups, simplicial approximation, fundamental group and covering spaces.	K4, K5
Knowledge Levels: K1-Remembering; K2-Understanding; K3-Applying; K4-Analyzing; K5-Evaluating; K6-Creating.		

Learning Pedagogy

Chalk and talk, Multimedia projection, e-content, Group discussion, Seminar, Interactive sessions, Tutorials, Assignment, Quiz, LMS

Assessment Tools

Assignments, Seminar, Test papers, End semester examination, Online assignments and tests

Semester IV	Code: PG20MT429	FRACTAL GEOMETRY	Total Hrs:**90** / Hrs/Week:**5**	Credits: **3**

Course Objective

- To learn basics of Fractal Geometry.
- To learn the mathematics of Fractals.

Syllabus

Pre-requisites – Mathematical background – A quick revision
(Chapter 1 of the text).
No questions shall be asked from this section. **(5 hours)**

Module 1: **Hausdorff measure and dimension**
Hausdorff measure, Hausdorff dimension, Calculation of Hausdorff dimension-Simple examples, Equivalent definitions of Hausdorff dimension, Finer definitions of dimension.
Alternative definitions of dimension
Box counting dimension, Properties and problems of box counting dimension, Modified box counting dimension, Packing measures and dimension.
(Chapter 2 , 3 Sections 3.1 to 3.4 of the text.) **(30 hours)**

Module 2: **Techniques for calculating dimensions**
Basic methods, Subsets of finite measure, Potential theoretic methods, Fourier transform methods.
Local structure of fractals
Densities, Structure of 1-sets, Tangents to s-sets.
(Chapter 4 & 5 of the text.) **(25 hours)**

Module 3: **Projections of fractals**
Projections of arbitrary sets, Projections of s-sets of integral dimension,
Products of fractals – Product formulae
(Chapter 6 & 7 of the text) **(18 hours)**

Module 4: **Intersections of fractals**
Intersection formulae for fractals, Sets with large intersection.
(chapter 8 of the text) **(12 hours)**

Text Books:

1. **Kenneth Falconer, Fractal Geometry Mathematical Foundations and Applications, John Wiley & Sons, New York.**

References:

1. Falconer K.J, The Geometry of Fractal sets, Cambridge University Press, Cambridge.
2. Barnsley M.F, (1988), Fractals everywhere, Academic press, Orlando, FL.
3. Mandelbrot B.B, (1982), The Fractal Geometry of Nature, Freeman, San Francisco.

4. Peitgen H.O and Richter P.H, (1986), The Beauty of Fractals, Springer, Berlin.
5. Tamas Vicsek, Fractal Growth Phenomena, Second edition, World Scientific.

QUESTON PAPER PATTERN

Module	Part A (Wt. : 1) Short Answer	Part B (Wt. : 2) Short Essay	Part C (Wt. : 5) Long Essay	Total
I	4	3	1	8
II	3	2	1	6
III	2	2	1	5
IV	1	1	1	3
Total No. of Questions	10	8	4	22
No. Questions to be answered	8	6	2	16

Course Outcomes

CO No.	Upon completion of this course, the students will be able to:	Knowledge Level
1	Analyse Hausdorff measure and dimension employ them to model and solve various problems.	K4, K6
2	Explain techniques for calculating dimensions	K3
3	Attain a clear theoretical understanding of Projections and intersection of fractals	K1
Knowledge Levels: K1-Remembering; K2-Understanding; K3-Applying; K4-Analyzing; K5-Evaluating; K6-Creating.		

Assessment Tools

Chalk and talk, Multimedia projection, e-content, Group discussion, Seminar, Interactive sessions, Tutorials, Assignment, Quiz, LMS

Learning Pedagogy

Assignments, Seminar, Test papers, End semester examination, Online assignments and tests

Elective Group E

Semester **IV**	Code: **PG20MT430**	**FINANCIAL MATHEMATICS**	Total Hrs:**90** Hrs/Week:**5**	Credits: **3**

Course Objective

- Introduce the basic idea of pricing by arbitrage
- Introduces the idea of a martingale measure for price processes
- Learn the 'Fundamental theorem of asset pricing'
- Investigate Completeness of markets

Syllabus

Module 1: **Pricing of Arbitrage**
Introduction: Pricing and Hedging, Single-Period Option Pricing Models, A General Single- Period Model, A Single- Period Binomial Model, Multi-Period Binomial Models, Bounds on Option Prices
(Chapter:- 1 Section 1.1 to 1.6 of the text) (24 hours)

Module 2: **Martingale Measures**
A General Discrete-Time Market Model, Trading Strategies, Martingales and Risk-Neutral Pricing, Arbitrage Pricing: Martingale Measures, Strategies Using Contingent Claims, Example: The Binomial Model, From CRR to Black-Scholes
(Chapter:- 2 Section 2.1 to 2.7 of the text) (22 hours)

Module 3: **The First Fundamental Theorem**
The Separating Hyper Plane Theorem in Rn, Construction of Martingale Measures, Path wise Description, Examples, General Discrete Models.
(Chapter:- 3 Section 3.1 to 3.5 of the text) (22 hours)

Module 4: **Complete Markets**
Completeness and Matringake Representation, Completeness for Finite Market Models, The CRR Model, The Splitting Index and Completeness, Incomplete Models: The Arbitrage Interval, Characterisation of Complete Models.
(Chapter:- 4 Section 4.1 to 4.6 of the text) (22 hours)

Text Books:

1. **Robert J Elliott, P. Ekkehard Kopp, Mathematics of Financial Markets, Second edition, Springer.**

References:

1. L.U. Dothan, Prices in Financial Markets, Oxford University Press, New York, 1990
2. D. Duffle, Future markets, Prentice-Hall, Englewood cliffs, N.J, 1989.

QUESTON PAPER PATTERN

Module	Part A (Wt. : 1) Short Answer	Part B (Wt. : 2) Short Essay	Part C (Wt. : 5) Long Essay	Total
I	3	2	1	6
II	3	2	1	6
III	2	3	1	6
IV	2	1	1	4
Total No. of Questions	10	8	4	22
No. Questions to be answered	8	6	2	16

Course Outcomes

CO No.	Upon completion of this course, the students will be able to:	Knowledge Level
1	Develop basic ideas of hedging and pricing by arbitrage in the discrete time setting of binomial tree models	K3, K6
2	Develop idea of a martingale measure for price processes	K3, K6
3	Examine fundamental theorem of asset pricing in the setting of finite market models	K3
4	Evaluate completeness of markets	K4
Knowledge Levels: K1-Remembering; K2-Understanding; K3-Applying; K4-Analyzing; K5-Evaluating; K6-Creating.		

Learning Pedagogy

Chalk and talk, Multimedia projection, e-content, Group discussion, Seminar, Interactive sessions, Tutorials, Assignment, Quiz, LMS

Assessment Tools

Assignments, Seminar, Test papers, End semester examination, Online assignments and tests

Semester IV	Code: PG20MT431	THEORY OF WAVELETS	Total Hrs:**90** Hrs/Week:**5**	Credits: **3**

Course Objective

- Introduction of applied structure through wavelets.
- To familiarize the knowledge on applications of Fourier transforms

Syllabus

Pre-requisites:- Linear Algebra, Discrete Fourier Transforms, Elementary Hilbert Space theorem. (No questions shall be asked from these sections.)

Module 1: Construction of Wavelets on $\mathbf{Z}_N$: The First Stage.
(Chapter – 3 Section 3.1 of the text) **(20 hours)**

Module 2: Construction of Wavelets on $\mathbf{Z}_N$: The Iteration Step, Examples – Haar, Shannon and Daubechies).
(Chapter – 3 Section 3.2 & 3.3 of the text) **(20 hours)**

Module 3: $l_2(\mathbf{Z})$, Complete Orthonormal sets in Hilbert Spaces, $L_2[-p , p]$ and Fourier Series.
(Chapter – 4 Section 4.1, 4.2 & 4.3 of the text) **(20 hours)**

Module 4: The Fourier Transform and Convolution on $l_2(\mathbf{Z})$, First-stage Wavelets on $\mathbf{Z}$, The Iteration step for Wave lets on Z, Examples- Haar and Daubechies.
(Chapter – 4 Section 4.4, 4.5, 4.6 & 4.7 of the text) **(30 hours)**

Text Books:

1. **Michael W. Frazier, An introduction to Wavelets through Linear Algebra, Springer-Verlag, 2000.**

References:

1. Mayer, Wavelets and Operators, Cambridge University Press, 1993.
2. Chui, An Introduction to Wavelets, Academic Press, Boston, 1992.

QUESTON PAPER PATTERN

Module	Part A (Wt. : 1) Short Answer	Part B (Wt. : 2) Short Essay	Part C (Wt. : 5) Long Essay	Total
I	3	2	1	6
II	2	2	1	5
III	2	2	1	5
IV	3	2	1	6
Total No. of Questions	10	8	4	22
No. Questions to be answered	8	6	2	16

Course Outcomes

CO No.	Upon completion of this course, the students will be able to:	Knowledge Level
1	Construct Wavelets on Z_N.	K6
2	Distinguish Haar, Shannon and Daubechies Wavelets.	K2
3	Infer the use of Fourier Analysis and Wavelet Analysis in Signal Processing.	K4
4	Describe Fourier Transform and Convolutions.	K2
Knowledge Levels: K1-Remembering; K2-Understanding; K3-Applying; K4-Analyzing; K5-Evaluating; K6-Creating.		

Learning Pedagogy

Chalk and talk, Multimedia projection, e-content, Group discussion, Seminar, Interactive sessions, Tutorials, Assignment, Quiz, LMS

Assessment Tools

Assignments, Seminar, Test papers, End semester examination, Online assignments and tests

Semester IV	Code: PG20MT432	CLASSICAL MECHANICS	Total Hrs:**90** / Hrs/Week:**5**	Credits: **3**

Course Objective

- To understand the Lagrangian and Hamiltonian equations for dynamical systems.

Syllabus

Module 1: Generalized coordinates, the Principle of least action, Galileo's relativity principle, the Legrangian for a free particle, Legrangian for a system of particle, energy, momentum, centre of mass, angular momentum, motion in one dimension, determination of the potential energy from the period of oscillation, the reduced mass, motion in a central field.
(Section 1 to 9, 11 to 14 of the text) **(24 hours)**

Module 2: Free oscillation in one dimension, angular velocity, the inertia tensor, angular momentum of a rigid body, the equation of motion of a rigid body, Eulerian angle, Euler's equation.
(Section 21, 31 to 36 of the text) **(20 hours)**

Module 3: The Hamilton's equation, the Routhian, Poisson brackets, the action as a function of the coordinates, Maupertui's principle.
(Section 40 to 44 of the text) **(24 hours)**

Module 4: The Canonical transformation, Liouville's theorem, the Hamiltonian – Jacobi equation, separation of the variables, adiabatic invariants, canonical Variables
(Section 45 – 50 of the text) **(22 hours)**

Text Books:

1. **L. D. Landau and E. M. Lifshitz - Mechanics, (Third Edition) (Butter worth – Heinenann)**

References:

1. M. G. Calkin, Lagrangian and Hamiltonian Mechanics, Allied
2. Herbert Goldstein, Classical mechanics, Narosa
3. K C Gupta, Classical mechanics of particles and Rigid Bodies, Wiley Eastern

QUESTON PAPER PATTERN

Module	Part A (Wt. : 1) Short Answer	Part B (Wt. : 2) Short Essay	Part C (Wt. : 5) Long Essay	Total
I	3	2	1	6
II	2	2	1	5
III	3	2	1	6
IV	2	2	1	5
Total No. of Questions	10	8	4	22
No. Questions to be answered	8	6	2	16

Course Outcomes

CO No.	Upon completion of this course, the students will be able to:	Knowledge Level
1	Understand the formation of differential equations which will help to study the dynamics of mechanical systems.	K2, K5, K6
Knowledge Levels: K1-Remembering; K2-Understanding; K3-Applying; K4-Analyzing; K5-Evaluating; K6-Creating.		

Learning Pedagogy

Chalk and talk, Multimedia projection, e-content, Group discussion, Seminar, Interactive sessions, Tutorials, Assignment, Quiz, LMS

Assessment Tools

Assignments, Seminar, Test papers, End semester examination, Online assignments and tests

PROJECT REPORT - GUIDELINES

Project evaluation is conducted at the end of the programme.

CREDITS : 1

Internal : Components and Weightage

Components	Weightage
Relevance of the topic and analysis	2
Project content and presentation	2
Project viva	1
Total	**5**

External: Components and Weightage

Components	Weightage
Relevance of the topic and analysis	3
Project content and presentation	7
Project viva	5
Total	**15**

COMPREHENSIVE VIVA-VOCE - GUIDELINES

Comprehensive viva-voce is conducted at the end of the programme.

CREDITS : 2

Internal :

Components	Weightage
Comprehensive viva-voce(all courses from first semester to fourth semester)	5
Total	**5**

External:

Components	Weightage
Comprehensive viva-voce(all courses from first semester to fourth semester)	15
Total	**15**

M.Sc. DEGREE MODEL QUESTION PAPER

First Semester M. Sc Mathematics

LINEAR ALGEBRA

Time: 3 hrs. Max. Weight: 30

PART A

(Answer any eight questions. Each question has weight 1)

1. Are the vectors (1, 1, 2, 4), (2, -1, -5, 2), (1, -1, -4, 0), (2, 1, 1, 6) linearly independent in R^4.
2. State two conditions that two matrices A and B are row - equivalent.
3. Find the explicit expression of the linear transformation T: $R^2 \rightarrow R^2$ given by T (2,3) = (4,5) and T (1, 0) = (0, 0).
4. Let V be the vector space of all $n \times n$ matrices over the field F, and let B be a fixed $n \times n$ matrix. If T (A) = AB – BA. Verify that T is a linear transformation from V into V.
5. Define annihilator of a subspace of a vector space V. If W_1 and W_2 are subspaces of a finite dimensional vector space V such that $W_1 \subseteq W_2$. Show that $W_2^0 \subseteq W_1^0$.
6. Prove that a linear combination of n-linear functions is n-linear.
7. If A is an invertible $n \times n$ matrix over a field, show that det A $\neq 0$.
8. If $\sigma_1 = 2, \sigma_2 = 3, \sigma_3 = 4, \sigma_4 = 1$ and $\tau_1 = 3, \tau_2 = 1, \tau_3 = 2, \tau_4 = 4$;
   (i) is σ odd or even? (ii) is τ odd or even? (iii) find $\sigma\tau$ and $\tau\sigma$.
9. If $T^2 = T$, prove that T is diagonalizable.
10. Let V be a real vector space and E is a projection. Prove that (I – E) is also a projection. Also find $(I + 2E)^{-1}$.

(8×1=8)

PART B

(Answer any six questions. Each question has weight 2)

11. Show that $\{\alpha + i\beta, \gamma + i\delta\}$ is a basis for C_R if and only if $\alpha\delta - \beta\gamma \neq 0$.
12. Let V be the vector space of all 2×2 matrices over the field R. Let W_1 be the set of matrices of the form $\begin{bmatrix} x & -z \\ y & z \end{bmatrix}$ and W_2 be the set of matrices of the form $\begin{bmatrix} a & b \\ -a & c \end{bmatrix}$. Prove that W_1 and W_2 are subspaces of V and also find the dimension of $W_1 \cap W_2$.
13. Find the Range, null space, rank and nullity of the linear transformation T: $R^2 \rightarrow R^3$ defined by $T(x_1, x_2) = (x_1 + x_2, x_1 - x_3, x_2)$.

14. Let $B = \{\alpha_1,\ \alpha_2,\ \alpha_3\}$ be the basis for C^3 defined by $\alpha_1 = (1, 0, -1)$; $\alpha_2 = (1, 1, 1)$; $\alpha_3 = (2, 2, 0)$. Find the dual basis B^* for V^*.

15. If W_1 and W_2 are subspaces of a finite dimensional vector space V. Prove that
    i) $(W_1 + W_2)^0 = W_1^0 \cap W_2^0$;
    ii) $(W_1 \cap W_2)^0 = W_1^0 + W_2^0$.

16. Let K be a commutative ring with identity. Show that the determinant function on 2×2 matrices A over K is alternating and 2-linear as functions of columns of A.

17. Let V be an n-dimensional vector space over F. Find the characteristic polynomials of the identity operator and the zero operator.

18. If a, b and c are elements of a field F and $A = \begin{bmatrix} 0 & 0 & c \\ 1 & 0 & b \\ 0 & 1 & a \end{bmatrix}$ Prove that the characteristic polynomial and minimal polynomial for A is $x^3 - ax^2 - bx - c$.

(6×2=12)

PART C

(Answer any two questions. Each question has weight 5)

19. a) Show that the vectors $\alpha_1 = (1,0,-1)$; $\alpha_2 = (1,2,1)$; $\alpha_3 = (0,-3,2)$ form a basis for R^3. Find the coordinates of each of the standard basis vectors in R^3 relative to the ordered basis $B = \{\alpha_1, \alpha_2, \alpha_3\}$.
    b) If W_1 and W_2 are subspaces of a finite dimensional vector space V show that $W_1 + W_2$ is finite dimensional and $\dim(W_1 + W_2) = \dim(W_1) + \dim(W_2) - \dim(W_1 \cap W_2)$.

20. Let T be the linear operator on R^2 defined by $T(x_1, x_2) = (-x_2, x_1)$,
    a) What is the matrix of T in the standard ordered basis for R^2?
    b) What is the matrix of T in the ordered basis $B = \{\alpha_1, \alpha_2\}$ where $\alpha_1 = (1, 2)$ and $\alpha_2 = (1, -1)$?
    c) Prove that for every real number c the operator (T - cI) is invertible.
    d) Prove that if B is any ordered basis for R^2 and $[T]_B = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix}$, show that $A_{12}\, A_{21} \neq 0$.

21. If K is a commutative ring with identity and let A and B be $n \times n$ matrices over K, show that det $AB = (det\ A)\ (det\ B)$.

22. State and prove Cayley - Hamilton theorem for linear operators.

(2×5=10)

M.Sc. DEGREE MODEL QUESTION PAPER

First Semester M. Sc Mathematics

GRAPH THEORY

Time: 3 hrs. Max. Weight: 30

PART A

(Answer any eight questions. Each question has weight 1)

1. Draw Peterson graph and show that it is not 1-factorable.
2. Define chromatic number $\chi(G)$ of a graph G and determine the chromatic number of the Herschel graph.
3. Determine the values of the parameters α, β, α' and β' for K_5.
4. Prove that an Eulerian graph is bridgeless.
5. Show that a subset S of V is independent if and only if V \ S is a covering of Graph G.
6. Define Eulerian and Hamiltonian graph by means of an example.
7. For any simple planar graph prove that $\delta(G) \leq 5$.
8. Show that Petersen graph P is nonplanar.
9. Define Dual of a plane graph using an example.
10. Define domination number γ(G) of a graph G. Find the domination number of Petersen graph.

(8×1=8)

PART B

(Answer any six questions. Each question has weight 2)

11. A matching M of a Graph G is maximum if and only if G has no M-augmenting path.
12. Let G be a simple graph with $n \geq 3$ vertices. If for every pair of nonadjacent vertices, v of G, $d(u) + d(v) \geq n$ then prove that G is Hamiltonian.
13. Prove that closure of G is well defined.
14. If G is k –critical then prove that $\delta \geq k - 1$.
15. Prove that a graph is planar if and only if it is embeddable on a sphere.
16. Show that K_5 is nonplanar.

17. Show that a dominating set S of a graph G is a minimal dominating set of G if and only if for each vertex u of S, one of the following conditions holds:
    (i) U is an isolated vertex of G[S].
    (ii) There exists a vertex $v \in V\setminus S$ such that u is the only neighbour of v in S.

18. Define independence set and dominating set of a graph G. Show that every maximal independent set of a graph G is a minimal dominating set.

(6×2=12)

PART C

(Answer any two questions. Each question has weight 5)

19. State and prove Whitney's theorem.
20. State and prove Cayley's theorem.
21. State and prove if and only if condition for a graph to be Euler.
22. State and prove Brook's theorem.

(2×5=10)

M.Sc. DEGREE MODEL QUESTION PAPER

First Semester M. Sc Mathematics

REAL ANALYSIS

Time: 3 hrs. Max. Weight: 30

PART A

(Answer any eight questions. Each question has weight 1)

1. Define a separable space.
2. $\langle x_n \rangle$; n = 1, ..., ∞ defined in [0, 1] will have at least one cluster point. Justify.
3. Define uniform convergence of a sequence of functions defined on E.
4. Suppose $\{f_n\}$ is a sequence of functions defined on E and suppose that $|f_n(x)| \leq M_n$ ($x \in E$, n = 1, 2, ...). Then prove that $\sum f_n$ converges uniformly on E if $\sum M_n$ converges.
5. Show that limit cannot be interchangeable in a double sequence.
6. Define bounded variation of a function. Prove that a function of bounded variation is bounded.
7. Define a rectifiable path and its arc length.
8. Prove that for any bounded function f on [a, b], inf $U(P, f, \alpha) \leq$ sup $L(P, f, \alpha)$; the inf and sup being taken over all partitions P and α is a monotonically increasing function on [a, b].
9. If f_1 and $f_2 \in \mathbf{R}(\alpha)$ on [a, b], prove that $f_1 + f_2 \in \mathbf{R}(\alpha)$.
10. Define Riemann-Stieltjes integral. (8×1=8)

PART B

(Answer any six questions. Each question has weight 2)

11. Let f be a continuous real-valued function on a (sequentially) compact space. Then prove that f is bounded and assumes its maximum and minimum.
12. Let K be a compact metric space and $\langle f_n \rangle$ is an equicontinuous sequence of functions to a metric space Y that converges at each point of K to a function f. The prove that $\langle f_n \rangle$ converges to f uniformly on K.
13. Let X be a compact metric space, C(X) denotes the set of all complex valued, continuous, functions with domain X. For each $f \in C(X)$, define $d(f, g) = \| f - g \|$ where $\| f \| = \sup |f(x)|; x \in X$. Then show that (C(X), d) is a metric space.

14. Let $\{f_n\}$ is a sequence of functions differentiable on [a, b] and such that $\{f_n(x_0)\}$ converges for some $x_0 \in [a,b]$ and $\{f_n'\}$ converges uniformly on [a,b], then prove that $\{f_n\}$ converges uniformly on [a, b] to a function f and $f'(x) = \lim_{n\to\infty} f_n'(x)$, (a ≤ x ≤ b).

15. Let f be defined on [a, b]. Then prove that f is of bounded variation on [a, b] if and only if f can be expressed as the difference of two increasing functions.

16. Let f = (f_1, f_2, ..., f_n) be a rectifiable path defined on [a, b]. If c ∈ (a, b), prove that $\Lambda_f(a, b) = \Lambda_f(a, c) + \Lambda_f(c, b)$; where $\Lambda_f(x, y)$ is the arc length of f of [x, y].

17. If f ∈ **R** on [a, b] and if there is a differentiable function F on [a, b] such that F' = f, then prove that $\int_a^b f(x)dx$ = F(b) - F(a).

18. If f maps [a, b] into R^k, if f ∈ **R** for some monotonically increasing function α on [a, b], then
prove that | f | ∈ **R**(α) and $\left| \int_a^b f d\alpha \right| \leq \int_a^b |f| d\alpha$.

(6×2=12)

PART C

(Answer any two questions. Each question carries 5 weights)

19. a) Prove that a metric space X is compact if and only if it is both complete and totally bounded.
b) Prove that every continuous mapping of a compact metric space X into a metric space Y is uniformly continuous.

20. Suppose $f_n \to f$ uniformly on a set E in a metric space. Let x be a limit point of E, and suppose that $\lim_{t\to x} f_n(t) = A_n$ (n = 1, 2, 3, ...). Then prove that $\{A_n\}$ converges, and $\lim_{t\to x} f(t) = \lim_{n\to\infty} A_n$.

21. Consider a rectifiable path f defined on [a, b]. If x ∈ (a, b], let s(x) = $\Lambda_f(a, x)$ and let s(a) = 0 Then prove that
i) The function s so defined is increasing and continuous on [a, b].
ii) If there is no subinterval on [a, b] on which f is constant, then s is strictly increasing on [a, b].

22. Assume that α increases monotonically and α' ∈ **R** on [a, b]. Let f be a bounded real function on [a, b]. Then prove that f ∈ **R**(α) if and only if fα' ∈ **R** and $\int_a^b f d\alpha = \int_a^b f(x)\alpha'(x)dx$.

(2×5=10)

M.Sc. DEGREE MODEL QUESTION PAPER

First Semester M. Sc Mathematics

BASIC TOPOLOGY

Time: 3 hrs. Max. Weight: 30

PART A

(Answer any eight questions. Each question has weight 1)

1. Define discrete topology, cofinite topology, usual topologies.
2. Prove that second countability is a hereditary property.
3. Show that a subset A of a topological space X is dense in X if and only if for every non-empty open subset B of X, $A \cap B \neq \phi$.
4. Prove that every open surjective map is a quotient map.
5. Prove that every continuous image of a compact space is compact.
6. Prove that every second countable space is Lindeloff.
7. Let $f: X \rightarrow Y$ be a continuous function. Then prove that if X is connected then Y is also connected.
8. Prove that the topological product of any finite number of connected space is connected.
9. Let X be a locally connected space. Prove that the components of open subsets of X are open in X.
10. Prove that a compact subset in a Hausdorff space is closed.

(8×1=8)

PART B

(Answer any six questions. Each question has weight 2)

11. Prove that Metrisability is a hereditary property.
12. For a subset A of a space X, show that $\bar{A} = A \cup A'$.
13. Prove that every second countable space is first countable.
14. Prove that every separable space satisfies the countable chain condition.
15. Prove the following: (a) any two distinct components are mutually disjoint (b) every nonempty connected subset is contained in a unique component.
16. Prove that every path connected space is connected.

17. Prove that every regular Lindeloff space is normal.
18. Prove that all metric spaces are T_4.

(6×2=12)

PART C

(Answer any two questions. Each question has weight 5)

19. Prove the following:
    a) A subset of a space X is dense in X if and only if for every non empty open subset B of X, $A \cap B \neq \phi$.
    b) Prove that second countable space always contains a countable dense subset.
20. a) Prove that every continuous real valued function on a compact space is bounded and attains its extrema.
    b) Let X, Y be spaces, $x \in X$ and $f : X \to Y$. Suppose X is first countable at x. Then f is continuous at x if and only if for every sequence $\{f(x)\}$ which converges to x in X, the sequence $\{f(x_n)\}$ converges to $f(x)$ in Y.
21. a) Prove that a subset of R is connected if and only if it is an interval.
    b) Prove that every closed and bounded interval is compact.
22. For a topological space X prove that the following statements are equivalent.
    a) X is regular.
    b) For any $x \in X$ and any open set G containing x there exits an open set H containing x such that $\bar{H} \subset G$.
    c) The family of all closed neighbourhoods of any point of X forms a local base at that point.

(2×5=10)