Department of Mathematics

PONDICHERRY UNIVERSITY

UG Degree (BS Honours) with Research in Mathematics

NATIONAL EDUCATION POLICY (NEP 2020)

REGULATIONS-2023

1. INTRODUCTION:

- The NEP curriculum is implemented from the Academic Year 2023-24.

1.1. Major Highlights

- The Department of Mathematics launch Integrated UG (Honours/Honours with Research) with lateral entry– exit facility in all the years study.

1.2. Age Limit:

- As per UGC Norms.

2. SHORT-TITLES AND DEFINITIONS

Definitions

a) **"Credit**" One credit is equivalent to 15 hours of teaching (lecture or tutorial) or 30 hours of practical and/or field work or community engagement and service per semester.

b) "**Academic Year**" from June- May (2 semester).

c) "**Semester**" means 15-16 weeks of teaching-learning session of which two weeks shall be set apart for examination and evaluation;

d) **"Summer term"** is for 8 weeks during summer vacation. Internship/apprenticeship/work based vocational education and training can be carried out during the summer term, especially by students who wish to exit after two semesters or four semesters of study.

e) "**Grade**" means a letter grade assigned to a student in a Course for her/his performance at academic sessions as denoted in symbols of : O(outstanding), A+(Excellent), A(Very good), B+(Good), B(Above average), C(Average), P(Pass) F(Fail) and Ab(Absent) with a numeric value of O=10, A+=9, A=8, B+=7, B=6, C=5 P=4, and F=0, Ab=0;

f) "**Semester Grade Point Average (SGPA)**" is computed from the grades as a measure of the students' performance in agiven semester.

g) **"Cumulative GPA (CGPA)**" is the weighted average of all courses the student has taken in a given Programme;

2.1 Duration of the Programme

Students who exit with a UG certificate or UG diploma are permitted to re-enter within three years and complete the degree programme. Students may be permitted to take a break from the study, they are allowed to re- enter the degree programme within 3 years and complete the programme within the stipulated maximum period of seven years.

2.2 Eligibility for the UG Programmes

Pass in +2 with a minimum of 50% of marks with Mathematics or equivalent stage of education to Level-4 (Levels in NHEQF).

3.0. AWARDING OF UG CERTIFICATE, UG DIPLOMA, AND DEGREES

UG Certificate: Students who opt to exit after completion of the first year and have earned a minimum of 42 credits will be awarded a UG certificate if, in addition, they complete work based vocational course/internship of 4 credits during the summer vacation of the first year.

UG Diploma: Students who opt to exit after completion of the second year and have earned a minimum of 84 credits will be awarded the UG diploma if, in addition, they complete wok based vocational course/internship of 4 credits during the summer vacation of the second year.

3- year UG Degree: Students who wish to discontinue after the 3- year UG will be awarded a UG Degree in the Major discipline after successful completion of three years, earning a minimum of 124 credits and satisfying the minimum credit requirements as mentioned in the table below.

4- year UG Degree (Honours): A four-year UG Honours degree in the major discipline will be awarded to those who complete a four-year degree, earning a minimum of 164 credits and have satisfied the credit requirements as mentioned in table below.

4-year UG Degree (Honours with Research): Students who secure a minimum of 7.5 CGPA in the first six semesters and wish to undertake research at the undergraduate level can choose a research stream in the fourth year. They should do a research project or dissertation under the guidance of a faculty member of the University. The research project/dissertation will be in the major discipline. The students who secure a minimum of 164 credits, including 12 credits from a research project, will be awarded UG Degree (Honours with Research).

4.0. STRUCTURE OF THE UNDERGRADUATE PROGRAMME

Table 1: Breakup of Credits and Courses- Minimumrequirement (Integrated Programme)

Sl. No.	Component	3 Year UG	4 Year UG (Honours/research)
1	Major Disciplinary/Interdisciplinary Courses	60 Credits (15 Courses of 4 credits)	80 Credits (20 Courses of 4credits)
2	Minor Disciplinary/interdisciplinary Courses (Vocational programme included)	24 Credits (6 Courses of 4 Credits)	32 Credits (8 Courses of 4credits)
3	Multi-Disciplinary Courses	9 Credits (3 courses of 3 credits)	9 Credits (3 courses of 3credits)
4	Ability Enhancement Courses	12 Credits (4 courses of 3 credits)	12 Credits (4 courses of 3credits)
5	Skill Enhancement Course	9 Credits (3 courses of 3 credits)	9 Credits (3courses of 3credits)
6	Value-added courses	8 Credits (4 courses of 2 credits)	8 Credits (4 courses of 2credits)
7	Summer internship	(4credits- Included in Major courses of 60 credits)	(4 credits-Included in Major courses of80 credits)
7	Community engagement and service	2 Credits (1 course)	2 Credits (1 course)
8	Research Dissertation Project	-	12 Credits
9	Total	124	164

Note: Honours students not undertaking research will do 3 courses for 12credits in lieu of a project.

4.1 STRUCTURE OF THE UNDERGRADUATE PROGRAMME in Mathematics UNDER NEP

Sem	Levels of Course in Major/Minor	Focus of Course Structure	Major Discipline	Minor Discipline	Multi-disciplinary Courses (MD)*	Ability Enhancement courses (AEC)	Skill Enhancement Courses (SEC)	Value-added courses (VAC)	Total
I	100-199 *Foundation/Introductory courses.*	*-should equip students to take up advanced courses/ specialized coursework,-to choose disciplinary/interdisciplinary course of their interest prospective professional field*	Major 1 (4Cr) (100 level)	Minor 1 (4 Cr) (100 level)	MD-1 (3 Cr) *(Can be chosen from bouquet)* *1.Natural/Physical Sciences* *2.Math/Stati/Comp.Applicatio* *3. Lib.Information and Media.Sciences.* *4.Commerce&Management* *5.Humanities&Social sci*	Eng -1 (3 Cr) *Linguistic/communication Skills/critical reading/academic writing/cultural intellectual heritage of language /abilities to discuss/ debate*	SEC-1 (3 Cr) *(Practical skills, Hands on, soft skills and so on for employability in the disciplinary/interdisciplinary areas chosen)*	VAC-1 (2cr) Understanding India VAC-2 (2cr) Environmental Science/Edn)- (2cr)	**21**
II			Major-2 (4Cr) (100 level)	Minor 2 (4 Cr) (100 level)	MD-2 (3cr) *(Can be chosen from above)*	MIL -1 (3cr) *(Can be chosen from above)*	SEC-2 (3cr) *(Practical skills, Hands on, soft skills and so on for employability)*	VAC-3 *(2cr) Health & Well Being / Yoga /sports/fitness* *VAC-4 (2cr) Digital Technologies*	**21**
Students exiting the programme after securing 40 credits will be awarded UG Certificate in Mathematics provided they secure 4 credits in workbased vocational courses offered during summer term or internship / Apprenticeship in addition to 6 credits from skill-based courses earned during first and second semester.									
III	200-299 :*Intermediate level courses*	*Prerequisite for advanced level major courses*	Major 3 Major 4 (8 cr) 200level	Minor 3 (4 Cr) 200 level (Vocational)	MD-3 *(3cr)* *(Can be chosen from above)*	Eng -2 (3cr) *(Can be chosen from above)/abilities to discuss/ debate*	SEC- 3 (3cr) *(Can be chosen from above)*		21
IV			Major 5-7 (12 cr) (200 level)	Minor 4 (4 Cr) (200&above) (Vocational)		*MIL -2 (3 Cr)* (as above)		*Community Engagement and Service(2cr)*	21
Students exiting the programme after securing 80 credits will be awarded UG Diploma in Mathematics, provided they secure additional 4 credits in work based vocational courses offered during summer term or internship / Apprenticeship. Summer Internship could be initiated during holidays and continued to the Vth semester.									

V	300-399: HigherLevel courses	*Disciplinary/interdisciplinary course study for the award of degree*	Major 8-10 (12 cr) (300 level)	Minor 5 (4 Cr) (200&above) (Vocational)			Internship(4cr) (Major 11)		20
VI			Major 12-15 (16 cr) 300 level	Minor 6 (4 Cr) (200&above))					20
❖ Students who want to undertake 3-year UG programme will be awarded UG Degree in Mathematics upon securing 122 credits. ❖ A minimum of 12 credits will be allotted to the minor stream relating to vocational education and training spreading through 2, 3, 4 &5 semesters. Internship is included as the Major 11..									
VII	400-499: Advanced Courses	*Lectures with seminars/term papers/ /labs/hands on, internships, Research/projects and so on.* *(Research methodology/Statistics course for UG with Research)*	Major 16 Major 17 Major 18 (12 cr) (400 level)	Minor 7 Minor 8 (8 Cr) (300&above					20
VIII			Major 19 Major 20 (8 cr)(400level)			Research Project/Disssertation (12 Cr)			20
❖ Students will be awarded UG Degree (Honours) with Research in Mathematics provided they secure 164 credits ❖ Honours students not undertaking research will do 3 courses for 12 credits in lieu of a research project / Dissertation. Students of UG honours with research will choose a research component in the 4th year and complete research methodology courses and advanced courses in major/minor.									

4.2. Description of courses

(i) Major Discipline (60 to 80 Credits)

Major discipline is the discipline or subject of main focus and the degree will be awarded in that discipline. Students should secure the prescribed number of credits (not less than 50% of the total credits) through core courses in the major discipline. The major discipline would provide the opportunity for a student to pursue in-depth study of discipline. A student may choose to change the major discipline within the broad discipline at the end of the second semester provided all the prerequisites of the respective degree programme are fulfilled.

(ii) Minor Discipline (24 to 32 credits)

Minor discipline helps a student to gain a broader understanding beyond the major discipline. For example, if a student pursuing an Economics major obtains a minimum of 12 credits from a bunch of courses in Statistics, then the student will be awarded B.A. degree in Economics with a Minor in Statistics.

- *24 credits of minor courses in the 3-year programme can be Disciplinary or Interdisciplinary courses or a mix of both. 50% of the total credits from minors must be secured in the relevantsubject/discipline and another 50% of the total credits can befrom any discipline of students' choice.*
- 12 credits (50%) of the Minor (Disciplinary / Interdisciplinary) in the 3-year programme should be related to vocational education/training courses.

Type of Minor	Credits
Disciplinary/Interdisciplinary	12 cr
Disciplinary/Interdisciplinary vocational	12 cr

(iii) Multidisciplinary courses (MD): 9 credits

All UG students are required to undergo 3 introductory-level courses relating to any of the broad disciplines given below. These courses are designed and developed by every department for the benefit of other discipline students and are pooled by SAMS under 5 baskets for students to choose any 3 courses from 3 broader areas (one each from any three broad areas from below) from the basket. Studentsare not allowed to choose or repeat courses already undergone at the higher secondary level (12th class) under this category.

a. ***Natural and Physical Sciences:*** Students can choose basic courses from disciplines such as Natural Science, for example, Biology, Botany, Zoology, Biotechnology, Biochemistry, Chemistry, Physics, Biophysics, Astronomy and Astrophysics, Earth and Environmental Sciences,

and other related subjects.

b. ***Mathematics, Statistics, and Computer Applications:*** Courses under this category will facilitate the students to use andapply tools and techniques in their major and minor disciplines. The course may include training in programming software like Python among others and applications software like STATA, SPSS, Tally and similar others. Basic courses under this category will be helpful for science and social science in data analysis and the application of quantitative tools.

c. **Library, Information, and Media Sciences:** Courses from this category will help the students to understand the recent developments in information and media science (journalism,mass media, and communication)

d. ***Commerce and Management:*** Courses include business management, accountancy, finance, financial institutions, fintech and other related subjects.

e. ***Humanities and Social Sciences:*** The courses relating to Social Sciences, for example, Anthropology, Communication and Media, Economics, History, Linguistics, Political Science, Psychology, Social Work, Sociology and other related subjects will enable students to understand the individuals and their social behaviour, society, and nation. Students be introduced to survey methodology and available large-scale databases for India. The list of Courses that can include interdisciplinary subjects such as Cognitive Science, Environmental Science, Gender Studies, Global Environment & Health, International Relations, Political Economy and Development, Sustainable Development, Women's and Gender Studies and similar subjects. will be useful to understand society.

(iv) Ability Enhancement Courses (AEC): 12 credits

Modern Indian Language (MIL) & English language focused on language and communication skills.

Students are required to achieve competency in a Modern Indian Language (MIL) and in the English language with special emphasis on language and communication skills. The courses aim at enabling the students to acquire and demonstrate the core linguistic skills, including critical reading and expository and academic writing skills, that help students articulate their arguments and present their thinking clearly and coherently and acquaint with the cultural and intellectual heritage of languages.

(v) Skill Enhancement Courses (SEC): 9 credits

These courses are aimed at imparting practical skills, hands-on training, soft skills, and other skills to enhance the employability of students. The institution may design courses as per the students' needs and available institutional resources. Skill based courses could be related to disciplinary/interdisciplinary minors and vocational education programmes chosen/offered.

Value-Added Courses (VAC) Common to All UG Students: 8 credits

a) ***Understanding India:*** This course aims at enabling the students to acquire and demonstrate the knowledge and understanding of contemporary India with its historical perspective, the basic framework of the goals and policies of national development, and the constitutional obligationswith special emphasis on constitutional values and fundamental rights and duties. The course would also focus on developing an understanding among student- teachers of the Indian knowledge systems, the Indian education system, and the roles and obligations of teachers to the nation in general and to the school/community/society. The course will attempt to deepen knowledge about and understanding of India's freedom struggle and of the values and ideals that it represented to develop an appreciation of the contributions made by people of all sections and regions of the country, and help learners understand and cherish the values enshrined in the Indian Constitution and to prepare them for their roles and responsibilities as effective citizens of a democratic society.

b) ***Environmental Science/Education:*** This course seeks to equip students with the ability to apply the acquired knowledge, skills, attitudes, and values required to take appropriate actions for mitigating the effects of environmental degradation, climate change, and pollution,effective waste management, conservation of biological diversity, management of biological resources, forest and wildlife conservation, and sustainable development and living. The course will also deepen the knowledge and understanding of India's environment in its totality, its interactive processes, and its effects on the future qualityof people's lives.

c) ***Digital and Technological Solutions***: Courses in cutting- edge areas that are fast gaining prominences, such as Artificial Intelligence (AI), 3-D machining, big data analysis, machine learning, drone technologies, and Deep learning with important applications to health, environment, and sustainable living that will be woven into undergraduate education for enhancing the employability of the youth.

d) ***Health & Wellness, Yoga Education, Sports, and Fitness:*** Course components relating to health and wellness seek to promote an optimal state of physical, emotional, intellectual, social, spiritual, and environmental well-being of a person. Sports and fitness activities will be organized outside the regular institutional working hours. Yoga education would focus on preparing the students physically and mentally for the integration of their physical, mental, and spiritual faculties, and equipping them with basic knowledge about one's personality, maintaining self- discipline and self-control, to learn to handle oneself wellin all life situations.

(vi) Vocational Training/Education: 12 Credits

These courses are meant to provide the students with adequate knowledge and skills for employment and entrepreneurship. Departments are expected to incorporate the requirements of related industries while designing these courses to groom the students to take up gainful employment or becoming entrepreneurs. Vocational education courses designed by each department should relate the skills provided with the content of general education in order to ready the students for work at each exit point of the programme. A minimum of 12 credits will be allotted to the minor stream relating to vocational education and training.

(vii) summer Internship: 4Credits

- The Mathematics Departments have network with R&D Labs/PSUs/Govt. Departments/Academic Institutions for facilitating student internships.
- The transformed education should improve employability of students by providing internships/skill development.
- Opportunities for Internships with local industry, businesses, artists and craft persons to improve the employability of students.

All students will undergo internships / Apprenticeships in a firm, industry, or organization or Training in labs with faculty and researchers in their own or other HEIs/research institutions during the summer term. Students will be provided with opportunities for internships to actively engage with the practical side of their learning and, as a by-product, further improve their employability.

(viii) Community Engagement and Service: 2 Credits

The curricular component of 'community engagement and service' seeks to expose students to the socio-economic issues in societyso that the theoretical learnings can be supplemented by actual life experiences to generate solutions to real-life problems. This can be part of summer term activity or part of a major or minor course depending upon the major discipline. Community Engagement shall be conducted for a minimum of 2 weeks.

(ix) Research Project / Dissertation: 12 Credits

Students choosing a 4-Year Bachelor's degree (Honors with Research) are required to take up research projects under the guidance of a faculty member. The students are expected to complete the Research Project in the eighth semester.

(x) Audit courses: 0 credits

Audit courses offered do not carry any credits. Evaluation will be based on continuous assessment. Students may be given a pass or fail(P/F) based on the assessment that may

consist of class tests, homework assignments, and/or any other innovative assessment methodology suitable to the expected learning outcome, as determined by the faculty in charge of the course of study.

4.3. Levels of the Courses

Courses can be coded based on the academic rigor. The first four letters of the course code indicate the department/Centre, followedby the academic rigor level code in digits (For e.g., Engl 201). The coding structure follows:

0-99: Pre-requisite courses required to undertake an introductory course which will be a pass or fail course with no credits. It will replace the existing informal way of offering bridge courses that are conducted in some of the colleges/ universities.

100-199: Foundation or introductory courses that are intended for students to gain an understanding and basic knowledge about the subjects and help decide the subject or discipline of interest. These courses generally would focus on foundational theories, concepts, perspectives, principles, methods, and procedures of critical thinking in order to provide a broad basis for taking up moreadvanced courses.

200-299: Intermediate-level courses including subject-specific courses intended to meet the credit requirements for minor or major areas of learning. These courses can be part of a major and can be pre-requisite courses for advanced-level major courses.

300-399: Higher-level Courses which are required for majoring in a disciplinary/interdisciplinary area of study for the award of a degree.

400-499: Advanced Courses which would include lecture courses with practicum, seminar-based course, term papers, research methodology, advanced laboratory experiments/software training, research projects, hands-on-training, internship/apprenticeship projects at the undergraduate level or First year post-graduate theoretical and practical courses.

4.4 Credit-hours for different types of courses

A three-credit lecture course in a semester means three one-hour lectures per week with each one-hour lecture counted as one credit. One credit for tutorial work means one hour of engagement per week.

A one-credit course in practicum or lab work, community engagement and services, and fieldwork in a semester mean two- hour engagement per week. In a semester of 15 weeks duration, a one-credit practicum in a course is equivalent to 30 hours of engagement. A one-credit of Seminar or Internship or Studio activities or Field practice/projects or Community engagement and service means two-hour engagements per week. Accordingly, in a semester of

15 weeks duration, one credit in these courses is equivalent to 30 hours of engagement.

- ***Lecture courses:*** Courses involving lectures relating to a field or discipline by an expert or qualified personnel in a field of learning, work/vocation or professional practice
- ***Tutorial:*** Courses involving problem solving and discussions relating to a field or discipline.
- ***Seminar:*** A course requiring students to participate in structured discussion/conversation or debate focused on assigned tasks/readings, current or historical events, or shared experiences guided or led by an expert or qualified personnel in a field of learning, work/vocation or professional practice.
- ***Internship:*** A course requiring students to participate in professional employment• related activity or work experience, or cooperative education activity with an entity external to the education institution, normally under the supervision of an employee of the given external entity.

 Laboratory work/activity: A course requiring students to discover/practice application of a scientific or technical principles/theories. The course may require scientific, or research focused experiential work where students observe, test, conduct experiment(s) or practice application of principles/theories relating to field of learning, work/vocation or professional practice.

- ***Studio activities:*** Studio activities involve engagement of students in creative or artistic activities. Studio-based activities involve visual- or aesthetic-focused experientialwork.
- ***Workshop-based activities:*** Courses involving workshop- based activities requiring engagement of students in hands- on activities related to work/vocation or professional practice.

 Field practice/projects: Courses requiring students to participate in field-based learning/project generally under the supervision of an employee of the given external entity.

5. Continuous Assessment and End semester Examination marks and evaluation of skill based/vocational courses/ Internships and other hands on/field-based courses

- All theory courses in a UG programme shall carry a continuous assessment component of 40 marks and end semester assessment component of 60 marks.
- In case of skill-based courses, vocational education courses, internships, practical, lab/field/project works, community service and related skill-based activities, the

evaluation pattern may be decided by the Programme Committee. The evaluation methods will be based on the learning outcomes planned for such courses following the NEP guidelines of Pondicherry University.

5.1 Continuous Assessment Component (Sessional)

- Evaluation will be based on continuous assessment carried out through activities spread over a complete semester based on the learning outcomes listed. Sessional work consists of class tests, at least one mid-semester examination, homework assignments, and any other innovative assessment methodology as determined by the faculty in charge of the course of study. Progress towards achievement of learning outcomes shall be assessed using the following: time-constrained examinations; closed-book and open-book tests; problem-based assignments; practical assignments; laboratory reports; observation of practical skills; individual project reports (case-study reports); team project reports; oral presentations, including seminar presentation; viva voce interviews; computerized adaptive assessments, examination on demand, modular certifications and other suitable assessments methods.
- Total Marks from continuous assessments may be up to 40% of the total. Departments/Centres/Schools need to design suitable continuous assessment models splitting the 40 marks into 2 to 4 different components including at least one mid semester test, duly approved by the PC/BOS.

5.2 End- Semester Examination and Evaluation

5.2.1 End semester examinations shall be conducted for all courses offered in the department after ensuring that the required number of classes and related activities are completed. The duration of the end semester examination may be 3 hours.

5.2.2 A schedule of End semester examinations will be announced by the department about 15 days ahead of the conductof examinations.

5.2.3 The responsibility of question paper setting, invigilation and valuation of answer papers lie with the course teachers. However, all assessments shall be conducted under the uniform practices of the department approved in the programme committee.

5.2.4 However, the departments/faculty members are free to decide the components of continuous assessment and the method of assessment based on the nature of the course and are expected to communicate these to students and respective HODs at the beginning of the semester.

5.2.5 Mid semester /end semester examinations schedule notified by the University in the academic calendar shall be uniformly followed.

QUESTION PAPER PATTTERN: MAXIMUM MARK: 60 TIME : 3 HOURS

Number of Questions	Allocation of questions	Choice Type	Mark per question	Total marks
5	2 questions from each Unit	Either or type	12	**5X12=60**

5.3 Minimum Marks for Pass

A student shall be declared to have passed the course only if she/he gets,

5.3.1 A minimum of 40% marks in end semester exam and

5.3.2 A minimum of 50% marks in aggregate when continuous assessment and end semester examination marks are put together.

5.4 Supplementary examination

5.4.1 A student who gets F grade in a course shall be permitted to register for the supplementary examination in the following semester or in the subsequent semesters.

5.4.2 A student who gets F grade in a course shall be given an option either to retain the previously awarded continuous assessment mark or to improve it, and the higher mark out ofthese two options will be considered for the supplementary examination.

A student who gets Ab grade inacourse/practicum/vocational course/internship/practicum or any other hands-on skill related course is mandated to repeat the course and undergo all the stages of assessment in subsequent semesters.

5.5 Attendance Requirement

No student who has less than 70% attendance in any course shall be permitted to participate in end semester examination and she/heshall be given 'Ab' grade, -failure due to lack of attendance. she/he shall be required to repeat that course as and when it is offered.

6. LETTER GRADES AND GRADE POINTS

Performance of students in each paper will be expressed as marksas well as Letter Grades.

Letter Grade	Grade Point
O (outstanding)	10
A+ (Excellent)	9
A (Very good)	8
B+ (Good)	7
B (Above average)	6
C (Average)	5
P (Pass)	4
F (Fail)	0
Ab (Absent)	0

In case of fractions the marks shall be rounded off to nearest integer.The class interval K will be the formula given below: K = (X-50)/6, where X is the highest mark secured.

According to K value, one of the following grading scheme will befollowed.

6.1.1 If K ≥ 5, then the grades shall be awarded as given in Table II.

Table II		
Range of Marks in %	**Letter Grade Points for**	**Letter Grade Points for**
X to (X-K)+1	O	10
(X-K) to (X-2K)+1	A+	9
(X-2K) to (X-3K)+1	A	8
(X-3K) to (X-4K)+1	B+	7
(X-4K) to (X-5K)+1	B	6
(X-5K) to 50	C	5
40 – 49	P	4
Below 40	F	0
bsent (Lack of Attendance)	Ab	0

6.1.2 If K<5, then the grades shall be awarded as given in Table III.

Table III		
ange of Marks in %	**GradePoints for**	**Letter GradePoints for**
80-100	O	10
71-79	A+	9
66-70	A	8
61-65	B+	7
56-60	B	6
50-55	C	5
40-49	P	4
Below 40	F	0
ent (lack of attendance)	Ab	0

The Semester Grade Point Average (SGPA) is computed from the grades as a measure of the student's performance in a given semester. The SGPA is based on the grades of the current term, while the Cumulative GPA (CGPA) is based on the grades in all courses taken after joining the programme of study.

Computation of SGPA and CGPA

The following procedure shall be followed to compute the Semester Grade Point Average (SGPA) and Cumulative Grade Point Average (CGPA):

The SGPA is the ratio of the sum of the product of the number of credits with the grade points scored by a student in all the courses taken by a student and the sum of the number of credits of all the courses undergone by a student, i.e. **SGPA** (Si) = Σ(Ci x Gi) / ΣCi

Where Ci is the number of credits of the i^{th} course and Gi is the grade point scored by the student in the i^{th} course.

(i) Example for Computation of SGPA where candidate has notfailed in any course.

ester	Course	redit	Letter Gr	Grade point	Credit Point (Credit xGrade)
I	Course 1	3	A	8	3 X 8 = 24
I	Course 2	4	B+	7	4 X 7 = 28
I	Course 3	3	B	6	3 X 6 = 18
I	Course 4	3	O	10	3 X 10 = 30
I	Course 5	3	C	5	3 X 5 = 15
I	Course 6	4	B	6	4 X 6 = 24
		20			139
	SGPA				139/20=6.95

(ii) Example for Computation of SGPA where candidate has failedin one course.

nester	Course	redit	tterGrade	Grade point	Credit Point (Credit xGrade)
I	Course 1	3	A	8	3 X 8 = 24
I	Course 2	4	B+	7	4 X 7 = 28
I	Course 3	3	B	6	3 X 6 = 18
I	Course 4	3	O	10	3 X 10 = 30
I	Course 5	3	C	5	3 X 5 = 15
I	Course 6	4	F	0	4 X 0 = 00
		20			115
	SGPA				115/20=5.75

(iii) Example for Computation of SGPA where candidate has failed in two courses.

nester	Course	Credit	LetterGrade	Grade point	Credit Point (Credit xGrade)
I	Course 1	3	A	8	3 X 8 = 24
I	Course 2	4	B+	7	4 X 7 = 28
I	Course 3	3	F	0	3 X 0 = 00
I	Course 4	3	B	6	3 X 6 = 18
I	Course 5	3	C	5	3 X 5 = 15
I	Course 6	4	F	0	4 X 0 = 00
		20			85
	SGPA				85/20=4.25

The CGPA shall also be calculated in similar way as shown in examples (i), (ii) and (iii) of SGPA for all subjects taken by the students in all the semesters. However, if any student fails more than once in the same subject, then while calculating CGPA, the credit and grade point related to the subject in which the student fails in multiple attempts will be restricted to one time only. The SGPA and CGPA shall be rounded off to 2 decimal points and reported in the transcripts.In case of audit courses offered, the students may be given (P) or (F) grade without any credits. This may be indicated in the mark sheet. Audit courses will not be considered towards the calculation of CGPA.

DEPARTMENT OF MATHEMATICS
PONDICHERRY UNIVERSITY

CURRICULUM FOR

FOUR YEAR B. Sc HONOURS / WITH RESEARCH
&
FIVE YEAR INTEGRATED M. Sc.
IN MATHEMATICS

UNDER NATIONAL EDUCATION POLICY
NEP-PU Regulation-April 2023
(academic year 2023-24 onwards)

AND
Mathematics Courses and Syllabi for
B. Tech Programs

(academic year 2024-25 onwards)

BSc Honours & 5 Year MSc: Semester-I

Course Code	Type	Credits	Title	Offered by
MATH 101	MAJOR -1	4	Calculus	Math
STAT	Minor -1	4	Descriptive Statistics (suggested)	Stat
MDC*-1	Multi-Disciplinary-1	3	Science and Society (suggested)	Phy
	Ability Enhancement -1	3	English – I	Eng
STAT	Skill Enhancement -1	3	Data Analysis with Excel-I	Stat
	Value Added- 1	2	Understanding India	Hist
	Value Added-2	2	Environmental Sciences	Envi
Semester Credits		**21**		

Semester-II

Course Code	Type	Credits	Title	Offered by
MATH 102	MAJOR -2	4	Matrices and Theory of Equations	Math
STAT	Minor -2	4	Probability Theory (suggested)	Stat
MDC*-2	Multi-Disciplinary-2	3	(suggested)	Sociology
	Ability Enhancement -2	3	English – 2	Eng
STAT	Skill Enhancement -2	3	Data Analysis with Excel-II	Stat
	Value Added- 3	2	Health and well Being	Ph-Edu
	Value Added-4	2	Digital Technologies	Comp
Semester Credits		**21**		

Semester-III

Course Code	Type	Credits	Title	Offered by
MATH 203	MAJOR -3	4	Introduction to Real Analysis-I	Math
MATH 204	MAJOR -4	4	Elements of Discrete Mathematics	Math
STAT	Minor -3	4	Distribution Theory(suggested)	Stat
MDC*-3	Multi-Disciplinary-3	3	(suggested)	Perf Arts
	Ability Enhancement -3	3	Modern Indian Language-1	Language
STAT	Skill Enhancement -3	3	Exploratory DATA Analysis using R	Stat
Semester Credits		**21**		

MDC*: In each semester select any one course from the bouquet of **multi-disciplinary courses.** Minimum three courses have to be completed. But, exactly one course from any of the following categories: -
1. Natural Sciences/Physical Sciences 2. Statistics/Computer Applications 3. Lib. Information and Media Sciences 4. Commerce and Management 5. Humanities and Social Sciences.

Semester-IV

Course Code	Type	Credits	Title	Offered by
MATH 205	MAJOR -5	4	Introduction to Real Analysis-II	Math
MATH 206	MAJOR -6	4	Group Theory	Math
MATH 207	MAJOR -7	4	Elements of Differential Equations	Math
STAT	Minor -4	4	Sampling Theory (suggested)	Stat
	Ability Enhancement -3	3	Modern Indian Language-2	Language
	Community Engagement	2	NSS/NCC	NSS
Semester Credits		**21**		

Semester-V

Course Code	Type	Credits	Title	Offered by
MATH 308	MAJOR -8	4	Topology of Metric Spaces	Math
MATH 309	MAJOR -9	4	Ring Theory	Math
MATH 310	MAJOR -10	4	Multivariable Calculus	Math
PHYS	Minor -5	4	Newtonian Mechanics and waves (suggested)	Physics
MATH 311	MAJOR- 11 (SEC-4)	4	Internship/Comprehensive Exam with Vivo voce	Maths
Semester Credits		**20**		

Semester-VI

Course Code	Type	Credits	Title	Offered by
MATH 312	MAJOR -12	4	Fundamentals of Complex Analysis	Math
MATH 313	MAJOR -13	4	Introduction to Linear Algebra	Math
MATH 314	MAJOR -14	4	Graph Theory	Math
MATH 315	MAJOR- 15	4	Linear Programing	Maths
PHYS	Minor -6	4	Thermal Physics (suggested)	Physics
Semester Credits		**20**		

Semester-VII

Course Code	Type	Credits	Title	Offered by
MATH 416	MAJOR -16	4	Advanced Algebra	Math
MATH 417	MAJOR -17	4	Topology	Math
MATH 418	MAJOR -18	4	Differential Equations and Special functions	Math
	Minor -7	4	From Annexure I	Math
	Minor -8	4	From Annexure I	Math
Semester Credits		**20**		

Semester-VIII

Course Code	Type	Credits	Title	Offered by
MATH 419	MAJOR -19	4	Advanced Real Analysis	Math
MATH 420	MAJOR -20	4	Advanced Linear Algebra	Math
Ability Enhancement -4				
MATH 499		12	Research Project Dissertation	Math
OR				
	Minor -9	4	From Annexure I	Math
MATH 427	Minor -10	4	Complex Analysis	Math
MATH 428	Minor -11	4	Measure and Integration	Math
Semester Credits		**20**		

Semester-IX

Course Code	Type	Credits	Title	Offered by
MATH 521	MAJOR -21	4	Functional Analysis	Math
MATH 522	MAJOR -22	4	Partial Differential Equations	Math
	Minor -12	4	From Annexure II	Math
	Minor -13	4	From Annexure II	Math
	Minor -14	4	From Annexure II	Math
Semester Credits		**20**		

Semester-X

Course Code	Type	Credits	Title	Offered by
	Minor -15	4	From Annexure II	Math
	Minor -16	4	From Annexure II	Math
Ability Enhancement -5				
MATH 599		12	Research Project Dissertation	Math
OR				
	Minor -17	4	From Annexure II	Math
	Minor -18	4	From Annexure II	Math
	Minor -19	4	From Annexure II	Math
Semester Credits		**20**		

LIST OF MINORS FOR 4th Year (ANNEXURE - I)

Course Code	Type / Semester	Credits	Title	Offered by
MATH 421	Minor	4	Cryptography	Math
MATH 422	Minor	4	Numerical Analysis	Math
MATH 423	Minor	4	Number Theory	Math
MATH 424	Minor	4	Calculus of Variations	Math
MATH 425	Minor	4	Galois Theory	Math
MATH 426	Minor	4	Lattice Theory	Math

LIST OF MINORS FOR 5th Year (ANNEXURE - II)

Course Code	Type / Semester	Credits	Title	Offered by
MATH 531	Minor	4	Differential Geometry	Math
MATH 532	Minor	4	Numerical Analysis for Ordinary Differential Equations	Math
MATH 533	Minor	4	q-Series in Number Theory	Math
MATH 534	Minor	4	Integral Transforms and Their Applications	Math
MATH 535	Minor	4	Wavelet Theory and Applications	Math
MATH 536	Minor	4	Graphs and Algebra	Math
MATH 537	Minor	4	Probability and Statistics	Math
MATH 538	Minor	4	Algebraic Number Theory	Math
MATH 539	Minor	4	Advanced Topics in Topology and Analysis	Math
MATH 540	Minor	4	Advanced Topology	Math
MATH 541	Minor	4	Commutative Algebra	Math
MATH 542	Minor	4	Discrete Dynamical Systems	Math
MATH 543	Minor	4	Advanced Special Functions	Math
MATH 544	Minor	4	Advanced Functional Analysis	Math
MATH 545	Minor	4	Non-Commutative Rings and Representations	Math
MATH 546	Minor	4	Algebraic Graph Theory	Math
MATH 547	Minor	4	Fixed Point Theory	Math
MATH 548	Minor	4	Graph Colouring	Math
MATH 901	Minor	4	Research Methodology	Math

ELIGIBILITY FOR LATERAL ADMISSION

Every student seeking admission in any year of the 5- year Integrated Master's program of the Department of Mathematics should have cleared the NTA_CUET entrance test after the 10+2 higher secondary schooling with Mathematics, Physics and Chemistry. Lateral entry will be governed under the PU-NEP Regulation April 2023 and its subsequent amendments.

MULTI DISPLINARY COURSE

Course Code	Type / Semester	Credits	Title	Offered by
MATH 100	MDC / odd & even	3	Basic Mathematics	Math

SKILL ENHANSEMENT COURSE

Course Code	Type / Semester	Credits	Title	Offered by
MATH 111	SEC-1 / odd & even	3	Latex for Mathematics	Math
MATH 121	SEC-2 / odd & even	3	Mathematical Methods with MATLAB	
MATH 211	SEC-3 / odd & even	3	Scilab for Mathematics	

MINOR COURSES (Offered For Mathematics Students)

Course Code	Type / Semester	Credits	Title	Offered by
MATH 200	Minor / odd	4	Numerical Methods	Math
MATH 201	Minor / even	4	Python	Math
MATH 202	Minor / odd	4	Elements of Mechanics	Math
MATH 300	Minor / even	4	Mathematical Modelling	Math
MATH 301	Minor / odd	4	Automata Theory	Math
MATH 302	Minor / even	4	Vector Analysis	Math

MINOR COURSES (Offered For Science Department Students)

These courses are designed for students from Statistics, Physics and etc. These courses will be floated depending on the number of students registering and the availability of the faculty. The number of students may be restricted depending on the available classroom facility and first-cum-first serve basis.

Course Code	Type / Semester	Credits	Title	Offered by
MATH 121	Minor / odd	4	Basic Calculus	Math
MATH 122	Minor / even	4	Basic Algebra and Theory of Equations	Math
MATH 221	Minor / odd	4	Fundamentals of Real Analysis	Math
MATH 222	Minor / even	4	Introduction to Differential Equations	Math
MATH 321	Minor / odd	4	Calculus of several variable	Math
MATH 322	Minor / even	4	Introduction to Linear Algebra	Math
MATH 429	Minor / odd	4	Vector Calculus	Math
MATH 430	Minor / even	4	Introductory Complex Analysis	Math

Mathematics Courses for B. Tech Programs of Computer Science, Banking Technology, Electronics, Green Energy and Nano Science Departments.

Code	Title	Semester	Credit	To Department
MATHE 111	Mathematics- I	1	4	Common for All
MATHE 121	Mathematics- II	2	4	Except Banking Tech
MATHE 122	Applied Linear Algebra	2	3	Banking Tech
MATHE 211	Discrete Mathematics	3	4	Computer & Bank Tech
MATHE 212	Numerical Techniques	3	3	Electronics Dept
MATHE 213	Mathematics- III	3	4	Green & Nano Tech

QUESTION PAPER PATTTERN: MAXIMUM MARK: 60 TIME : 3 HOURS

Number of Questions	Allocation of questions	Choice Type	Mark per question	Total marks
5	2 questions from each Unit	Either or type	12	**5X12=60**

Semester-I

MAJOR-1 MATH 101: CALCULUS (4 CREDITS)

Course Objectives:

1. Able to analyze the derivatives and anti-derivatives of functions.
2. To understand the concept of applications of derivatives and integration

	Course Outcome
CO 1	Analyse the methods and application of differentiation
CO 2	To find asymptotes and draw free hand diagram of a given function
CO 3	Analyse the methods and application of integration

Unit I: (Sections: 3.2-3.9, 4.1, 4.3, 4.4)
Derivative of standard functions, Application of derivatives - Increasing decreasing functions - Maxima minima, Test of concavity& convexity point of inflexion.

Unit II: (Sections: 2.6, 4.2, 10.8, 11.3, 11.4, 13.4)
Mean value theorems, Taylor theorem, Maclaurin's theorem, Polar coordinates and curvature, Asymptotes, Graphing in polar co-ordinates.

Unit III: (Sections: 5.1, 5.2, 5.3, 5.4, 5.5)
Definite integrals - Properties of definite integrals - Integral as the limits of a sum- Evaluation of integrals- Area and the mean value theorem, fundamental theorem of calculus , Substitution in definite integrals.

Unit IV: (Sections: 8.1, 8.2, 8.3, 8.4, 8.5)
Integration by parts, Integration of rational fractions-Reduction formulas- $\sin^n x$, $\cos^n x$, $\tan^n x$, $\cot^n x$, $\sec^n x$, $\text{cosec}^n x$, $\cos^m x \cos nx$, $\cos^m x \sin nx$, $\sin^n x \cos^m x$.

Unit V: (Sections: 5.6, 6.1, 6.2, 6.3, 6.4)
Areas between curves, Volume using cross section- Finding volume by slicing, Volumes of solids of revolution - Disk and washers- Cylindrical shell-Arc length-- Areas of surface of revolution.

Text Book

1. George B.Thomas, Maurice D.Weir and Joel Hass, Thomas' Calculus 12th Edition, Pearson Education, 2015.

Reference Books

1. Richard Courant and Fritz John, Introduction to Calculus and Analysis, Vol.I, Springer 1999.
2. Serge Lang A First course in Calculus 5th edition, Springer, 1999.
3. N. P. Bali, Integral Calculus, Laxmi Publications, Delhi 1991.
4. Richard Courant and Fritz John, Introduction to Calculus and Analysis, Volumes I & II Springer, SIE, 2004.
5. Serge Lang A First course in Calculus 5th edition, Springer, 1999.

Semester-II

MAJOR-2 MATH 102: MATRICES AND THEORY OF EQUATIONS
(4 CREDITS)

Course Objectives:

1. To introduce the idea of matrices and to learn about the algebra of matrices
2. To solve system of linear equations using matrix Theory

	Course Outcome
CO 1	To learn the relation between the co-efficient and roots of polynomial equations.
CO 2	To learn various methods for solving polynomial equations and study the nature & position of roots.
CO 3	Analytic Methods for solving the polynomial equation of degrees 3 & 4.

Unit I: (Sections 1.1, 1.2, 1.3,1.4,1.5 of [1])
Linear systems - Matrices - Dot product and Matrix multiplication - Properties of Matrix operation, Matrix transformations.

Unit II: (Sections 1.6,1.7,1.8[1])
Solutions of Linear systems of equations - Row echelon from reduced row echelon form – Polynomial interpolation - The inverse of a Matrix. - Linear Systems and inverses - LU- Factorization Method.

Unit III: (Sections 5.1,5-2,.5.3 of [2])
Division algorithm - Relation between roots and coefficients - Sum of the powers of the roots.

Unit IV: (section 5.4,5.5,5.6 ,5.7 of [2])
Reciprocal equations - Transformation of equations: - Multiple roots - Nature of position of roots - Sturm's Theorem.

Unit V: (Sections 5.8,5.9,5.10 of [2])
Cardan's Method for solving Cubic equations – Ferrari's Method for solving biquadratic equations - New Newton's Method- Horner's Method

Text Books

1. Bernard Kolman Drid R. Hill, Introductory Linear Algebra, (8e),Pearson India (2011)
2. S. Arumugam and A Thangaand Isaac, Set Theory Number System and Theory of Equations, New Gamma publishing house(1997.).

References:

1. Theory of Equations, Hari Kishan, Atlantic Publishers, 2022
2.Theory of Equations, Lalji Prasad, New Revised Edition, 2016

Semester-III

MAJOR-3 MATH 203: INTRODUCTION TO REAL ANALYSIS – I

Course Objectives: (4 CREDITS)

1. To study the importance of the LUB property of the real number system
2. To study the property of convergence sequence

	Course Outcome
CO 1	To discuss about the Bolzano Weierstrass theorem and recursive sequences
CO 2	To study about convergence of infinite series and various tests of convergence
CO 3	To understand the algebra of convergent series and rearrangement of infinite series

Unit I: (Sections 1.1, 1.2 and 1.3)

Algebra of the Real Number system – Upper and lower bounds – LUB property and its applications – Archimedean property – Greatest integer function – Density of rational numbers – Existence of n^{th} roots of positive real numbers – Nested intervals theorem.

Unit II: (Sections 1.4, 2.1, 2.2, 2.3 and 2.4)

Absolute value and Triangle Inequality – Subsets of R defined by inequalities – Convergent sequences – Definition and examples – Properties of algebra of limits of sequences – Bounded sequences – Sandwich Lemma – Cauchy sequences – Cauchy completeness of R - Monotone sequences – Geometric sequence – The number e - Nested intervals theorem.

Unit III: (Sections 2.5, 2.6, 2.7 and 2.8)

Some important limits – Cesaro's Theorem – Sequences diverging to $+\infty$. – Existence of a monotone sequence of a real sequence – Bolzano Weierstrass Theorem – Sequences definedrecursively.

Unit IV: (Sections 5.1 and 5.2)

Convergence and sum of an infinite series – Geometric series – Cauchy criterion – Algebra of convergent series – Absolutely convergent series – Comparison Test – Harmonic p-series – D'Alembert's ratio Test – Cauchy's Root Test – Integral Test – Cauchy's Condensation Test – Abel's Summation by parts Formula – Dirichlet's Test – Leibmitz Test for alternating series.

Unit V: (Section: 5.3 and 5.4)

Rearrangement of an infinite series – Definition and examples – Riemann's Theorem – Cauchy product of two infinite series – Merten's Theorem – Abel's Theorem on Cauchy product – Existence of decimal expansion – characterization and rational numbers.

Text Book:

1. Ajith Kumar and S.Kumaresan, ***A Basic Course in Real Analysis***, CRC Press (2014)

Reference Books:

1. Robert G. Bartle, Donald R. Sherbert, *Introduction to Real Analysis*; John Wiley and sons (Fourth Edition).
2. Kenneth A. Ross, *Elementary Analysis : The Theory of Calculus*, springer , 2e (2013).
3. Ajithkumar,S.Kumaresan, Bhasa Kumar Sarma , *A Foundation Course in Mathematics*, Narosa– 2018.

MAJOR-4 MATH: 204: ELEMENTS OF DISCRETE MATHEMATICS

(4 CREDITS)

Course Objectives:

1. Able to understand the concepts of sets and determine whether a relation is a function and identify the domain and range of a function.
2. Understand the ideas of the basis step and the inductive step in a proof by Mathematical induction and recurrence relations

	Course Outcome
CO 1	To understand the basic concepts of Permutations and combinatorics
CO 2	To familiarize the applications of Difference sequences and Catalan numbers.
CO 3	To understand the concepts and significance of lattices and Partition of numbers.

Unit I: (Sections: 0.1, 0.2, 1.1, 1.2, 1.3, 2.1, 2.2, 2.3, 2.4, 2.5)

Statements – Compound Statements – Contrapositive statements – Proofs in Mathematics (Types of proofs) – Direct proofs – Proof by cases – Proof by contradiction – Logic – Truth tables – The Algebra of Propositions – Logical arguments –Sets – Operations on sets – Binary relations – Equivalence relations – Partial orders.

Unit II: (Sections: 3.1, 3.2, 3.3, 4.1, 4.2, 4.3)

Functions – Inverses and composition – One-to-one correspondence and the cardinality of a set – The Integers – The Division algorithm – Divisibility – The Euclidean Algorithm – Prime numbers.

Unit III: (Sections: 5.1, 5.2, 5.3, 5.4, 6.1, 6.2)

Mathematical induction – Weak form and strong form – Recursively defined sequences – Solving recurrence relations – The characteristic polynomials – Solving recurrence relations – Generating functions – The principle of inclusion-Exclusion – The addition and multiplication rules.

Unit IV: (Sections: 6.3, 7.1, 7.2, 7.5, 7.6, 7.7)

The pigeonhole principle–Permutations – Combinations –Repetitions – Derangements – The binomial theorem.

Unit V: (Sections: 8.1, 8.2, 8.3, 8.4)

What is an Algorithm – Complexity – Searching and sorting – Enumeration of permutation and combination.

Text Books

Edgar G. Goodaire, Michael M. Parmenter, Discrete Mathematics with Graph Theory (Third Edition), PHI Learning Private Ltd., New Delhi - 2011.

Reference Books

1. Richard Johnson bauth, Discrete Mathematics, 5th Edition, Pearson Education Asia, New Delhi, 2002.
2. Ralph. R. Grimaldi - Discrete and Combinatorial Mathematics: An applied Introduction - 4th Edition, Pearson Education Asia, Delhi, 2002
3. C.L. Liu, Elements of Discrete Mathematics, The Mc Graw-Hill, India 1985.
4. Bernard Kolman, Robert C. Busby, Sharan Cutler Ross, Discrete Mathematical Structure, 4th Edition, Pearson Education Pvt. Ltd., New Delhi 2003

Semester-IV

MAJOR-5 MATH: 205: INTRODUCTION TO REAL ANALYSIS – II
(4 CREDITS)

Course Objectives:

1. To introduce the concept of limit and continuity of functions
2. To introduce the notion of differentiability and some fundamental results on differentiation.

	Course Outcome
CO 1	To learn some applications of differentiability of functions
CO 2	To introduce the Riemann theory of integration and the fundamental theorem of calculus
CO 3	To learn about pointwise and uniform convergences of sequence of functions

Unit I: (Sections 3.1, 3.2, 3.3, 3.4, 3.5 and 3.6 of [1])
Continuous functions– Algebra of continuous functions – ε-δ definition of continuity – Intermediate value theorem– Extreme value theorem– Monotonic function– Limit of a function – Limit at infinity.

Unit II: (Sections 4.1 and 4.2 of [1])
Differentiability of functions – Chain rule – Roll's theorem – Mean value theorems –Applications of mean value theorem – Inverse function theorem – Cauchy's form of mean value theorem.

Unit III: (Sections 4.3, 4.4, 4.5 and 4.6 of [1])
L'Hospital's rule–Darboux theorem – Taylor's theorem – Convex functions – Derivative test for convexity.

Unit IV: (Sections 6.1, 6.2, 6.3 and 6.4 of [1])
Riemann integration – Upper and lower sums –Properties of Riemann integration – Basic estimates for integrals – Fundamental theorem of calculus (I & II), Mean value Theorem for Integrals.

Unit V: (Sections 7.5 and 7.10 of [2])
Improper integrals (First and second kind) – Absolute Convergence – conditional convergence – integral test – Cauchy principal value.

Text book:

1. Ajith Kumar and S.Kumaresan, *A Basic Course in Real Analysis*, CRC Press (2014).
2. Richard R Goldberg, Methods of Real Analysis, Oxford and IBH Publishing Co. Pvt Ltd, New Delhi, Indian Edition 1970.

Reference Books

1. R.G. Bartle and D.R. Sherbert, Introduction to Real Analysis, Third Edition, Wiley India edition, 2000.
2. Kenneth A. Ross, *Elementary Analysis: The Theory of Calculus*, springer, 2e (2013).

MAJOR-6 MATH: 206: GROUP THEORY (4 CREDITS)

Course Objectives:

1. To introduce the concept of Group and Homomorphisms.
2. To introduce the notion of special subgroups and Symmetric group.

	Course Outcome
CO 1	To learn some special sub groups like Normal subgroups.
CO 2	To introduce the Coset concepts and Lagrange's Theorem.
CO 3	To learn about Automorphisms.

Unit I

Introduction to Groups - Definition and Examples of Groups – Elementary Properties of Groups – Subgroups - Subgroup Tests - Examples of Subgroups.

Unit II

Cyclic Groups - Properties of Cyclic Groups - Classification of Subgroups of Cyclic Groups - Permutation Groups - Cycle Notation - Properties of Permutations.

Unit III

Isomorphisms - Cayley's Theorem - Properties of Isomorphisms – Automorphisms.

Unit IV

Properties of Cosets - Lagrange's Theorem and Consequences, Normal Subgroups - Factor Groups - Applications of Factor Groups.

Unit V

Group Homomorphisms - Properties of Homomorphisms - The First Isomorphism Theorem.

Text Book:

Joseph A. Gallian, Contemporary Abstract Algebra, 8th Edition, Cengage Learning India Private Limited. **Chapters 2,3,4,5,6,7,9(except Internal Direct Products) and 10.**

Reference books

1 M. Artin: Algebra, Prentice-Hall of India, 1991.
2. I.N.Herstein: Topics in Algebra, Wiley Eastern Ltd., New Delhi, 1975.

MAJOR-7 MATH: 207 ELEMENTS OF DIFFERENTIAL EQUATIONS
(4 CREDITS)

Course Objectives:

1. To understand ordinary and first order partial differential equations and their applications
2. To enable students to understand solving the first and second order ODES and first order PDEs.

	Course Outcome
CO 1	To solve a system of first order ODEs
CO 2	To analyze the stability of a Dynamical System using Differential Equations and their solutions
CO 3	To Solve First Order Partial Differential Equations

Unit I:

Exact differential equations- Integrating factors – Linear differential equations- Bernoulli equation – Modeling: Electric circuits – Orthogonal trajectories of curves.

Unit II:

Homogeneous linear equations of second order – Second order homogeneous equations with constant coefficients – Case of complex roots- Complex exponential function – Differential operators – Modeling: Free oscillations – Euler-Cauchy equation – Existence and uniqueness theory – Wronskian.

Unit III:

Non homogeneous equations – Solution by undetermined coefficients – Solution by variation of parameters – Modeling of electric circuits – Higher order linear differential equations – Higher order homogeneous equations with constant coefficients.

Unit IV:

Introduction: vectors, matrices, eigenvalues – Introductory examples – Basic concepts and theory – Homogeneous systems with constant coefficients, phase plane, critical points – Criteria for critical points, Stability.

Unit V:

Non-linear first order PDEs : Compatible systems- Solutions of Quasi linear equations
Charpit's method- Special Types of Charpits Method, -Integral surfaces through a given curve-The Cauchy problem for Quasi Linear case and nonlinear first order PDEs

Text Book

Erwin Kreyszig, Advanced Engineering Mathematics, 8th Edition, John Wiley & Sons, 1999.
Unit-I: Sections 1.5-1.8; Unit-II: Sections 2.1-2.7; Unit-III: Sections 2.8-2.10, 2.13, 2.14;
Unit-IV: Sections 3.0-3.4;
K. Shankara Rao, Introduction to Partial Differential Equations, PHI Publications,
3rd Edition. 2011. – Chapter 1

Reference Books

1. George F. Simmons, Differential Equations, Tata McGraw-Hill, New Delhi, 1972.
2. Boyce and Di Prima, Differential Equations and Boundary Value Problems, Wiley,10th edition 2012.
3. Earl A. Coddington, An Introduction to Ordinary Differential Equations, Prentice Hall of India Private Ltd, 1991.

Semester-V

MAJOR-8 MATH: 308: TOPOLOGY OF METRIC SPACES

(4 CREDITS)

Course Objectives:

1. To study about some important inequalities and to introduce the notion of metric spaces
2. To study the Baire's category theorem, connected sets and homeomorphisms

	Course Outcome
CO 1	To learn complete metric spaces and to discuss some of the important results regarding completeness
CO 2	To introduce the notion of compactness and its properties
CO 3	To study about the improper integrals and varies tests of convergence for improper integrals

Unit I: (Section 3.10, 4.2, 4.3,5.3, 5.4, 5.5**)**

Metric Spaces – Definition – Examples – Holder inequality – Minkowski's inequality – Convergent sequence – Cauchy sequence – Equivalent metric spaces – Continuous functions on a Metric space – Open sets – Closed sets – Limit points.

Unit II: (Section 5.6, 6.1,6.2)

Oscillation of a function – $F_\sigma$set, $G_\delta$set – Dense and nowhere dense subsets –Baire's category Theorem – Subspaces – Connected sets – Connected subsets of R – Continuity and connectedness.

Unit III: (Section 6.3, 6.4)

Bounded sets – Totally bounded sets – Complete metric spaces – Cantor intersection theorem – Contraction mapping – Contraction mapping theorem.

Unit IV: (Section 6.5, 6.6, 6.7,6.8)

Compactness – Sequential compactness – Heine-Borel property – Finite intersection property- Continuity and compactness – Continuity of inverse functions – Uniform continuity.

Unit V: (Section 9.1, 9.2, 9.4)

Sequences and series of functions – The metric space C[a,b] – pointwise Convergence – Uniform Convergence – Cauchy's criterion for uniform convergence.

Text Book

R. Goldberg, Methods of Real Analysis, Oxford and IBH Publishing Co. Pvt. Ltd., 1970.

Reference Books

1. Ajith Kumar and S. Kumaresan, *A Basic Course in Real Analysis*, CRC Press (2014).
2. R.G. Bartle and D.R. Sherbert, Introduction to Real Analysis, Third Edition, Wiley India edition 2000.
3. S. Kumaresan, Topology of Metric spaces, Second Edition, Narosa Publishing House, 2005.
4. Pawan K. Jain and Khalil Ahmad, Metric Spaces, (Second Edition), Narosa Publishing House 2004.

MAJOR-9 MATH:309: RING TEORY (4 CREDITS)

Course Objectives:

1. To introduce the concept of Rings and Homomorphisms of Rings.
2. To introduce the notion of special subrings and Integral Domains.

	Course Outcome
CO 1	To learn some special Integral Domain like ED, PID and UFD.
CO 2	To introduce the Quotient ring concepts and Fundamental Theorem.
CO 3	To learn about Fields.

Unit I

Introduction to Rings - Motivation and Definition of Rings – Examples of Rings – Properties of Rings – Subrings - Definition and Examples of Integral Domains – Fields - Characteristic of a Ring.

Unit II

Ideals - Factor Rings - Prime Ideals and Maximal Ideals - Definition and Examples of Ring Homomorphisms - Properties of Ring Homomorphisms - The Field of Quotients.

Unit III

Polynomial Rings - The Division Algorithm and Consequences - Principal ideal domain - Factorization of Polynomials - Reducibility Tests - Eisenstein's Criterion- Irreducibility Tests.

Unit IV

Unique Factorization in $Z[x]$ - Divisibility in Integral Domains – Irreducibles and Primes - PID Implies Irreducible Equals Prime.

Unit V

Unique Factorization Domains – PID Implies UFD – $F[x]$ Is a UFD – Euclidean Domains –ED Implies PID – ED Implies UFD.

Text Book:

Joseph A. Gallian, Contemporary Abstract Algebra, 8th Edition, Cengage Learning India Private Limited.
Chapter 12 to Chapter 18.

Reference books

1 M. Artin: Algebra, Prentice-Hall of India, 1991.
2. I.N.Herstein: Topics in Algebra, Wiley Eastern Ltd., New Delhi, 1975.
3. David S. Dummit and Richard M. Foote, Abstract Algebra (Third Edition), John Wiley and sons, 2004

MAJOR-10 MATH: 310: MULTIVARIABLE CALCULUS (4 CREDITS)

Course Objectives:

1. To learn differentiation, partial differentiation, directional derivatives and gradients.
2. To learn about double and triple integrals.

	Course Outcome
CO 1	To apply the double and triple integrals to find volume and area.
CO 2	To learn maxima and minima of two and more variables
CO 3	To learn about some applications of integrals in other branches of sciences

Unit I (Sections: 1.5, 1.6, 2.1, 2.2, 2.3**):** The n-dimensional Euclidean space – Angle between the vectors - Graphs and level curves/ surfaces – Examples - Limits and continuity – Partial derivatives – Differentiability – The derivative matrix – The tangent planes.

Unit II (Sections: 2.4, 2.5, 2.6**):** The chain rule – Tangent to curves on surfaces - Algebra of derivatives - Gradients and directional derivatives – Tangent plane to a surface – Gradient and tangent planes – Implicit differentiation.

Unit III (Sections: 2.1, 3.2, 3.3, 3.4, 3.5**):** Higher order partial derivatives – Equality of mixed partial derivatives - Taylor's theorem – A second order Taylor formula - Maxima and minima – Critical points – First derivative test – Absolute maxima and minima on closed intervals - Second derivative test – Taylors formula near a critical point - Constrained extrema and Lagrange multipliers.

Unit IV (Sections: 5.1, 5.2, 5.3**):**
Volume and Cavalieri's principle – Double and iterated integrals – The double integral over a rectangle - Properties – Reduction to iterated integrals – The double integral over regions – Mean value theorem for double integrals.

Unit V (Sections: 5.4, 5.5, 5.6**):** Triple integrals over a box – Triple integrals by iterated integration – Double integrals in polar coordinates – Triple integrals in cylindrical and periodical coordinates – General change of variable formula – Applications of multiple integrals – Average value – coordinates of the center of mass – Moment of inertia.

Text Book : J.E. Marsden, A.J. Tromba and A. Weinstein, Basic Multivariable Calculus, Springer, 2004.

Reference Books

1. George B.Thomas, Jr. and Ross L. Finney, Calculus, 9th Edition, Pearson Education, 2006.
2. Richard Courant and Fritz John , Introduction to Calculus and Analysis, Volumes I & II, Springer, SIE, 2004.

MAJOR-11 MATH: 311: INTERNSHIP / COMPREHENSIVE EXAM WITH VIVO VOCE (4 CREDITS)

(Two Months in Industries / Universities / Research Institutes etc.)

Objective: The internship program for mathematics graduates aims to provide real-world experience, enhance mathematical skills, and offer opportunities to apply mathematical knowledge in various professional settings. The curriculum may enable mathematics undergraduates to work on practical projects.

Month 1: Foundation and Skill Development

Week 1-2: Orientation and Introduction to the Organization - Understanding the internship structure - Introduction to the team and projects - Introduction to specific mathematical problems in recent advancements of Mathematics

Week 3-4: Learning Basics in Program Specific Subject (e.g. Linear Algebra and Optimization, Differential Equations, Topology, Functional Analysis, Advanced Agebra, Graph Theory etc.)

Week 5-6: Mathematical Projects - Collaborate on real projects within the organization
- Apply mathematical concepts to solve problems - - Present project progress and results

Week 7-8: Final Project and Presentation - Work on an individual or group project
- Develop a presentation to showcase the project results - Presentation to the project supervisor.

Note: Students unable to arrange the above can make a project based on the first 2 years papers under the guidance of the Department faculties and should go through a comprehensive Exams and vivo under the approval of the Program Committee Meetings.

Evaluation Process:

1. Performance Assessment: Regular feedback from mentors on the intern's progress.
- Evaluation of assignments, projects, and tasks - Interns should have a mid-term review with their mentors to discuss their progress/improvement.

2. Final Evaluation: Evaluation of the final project, presentation, and report.
- Assessment of learning skills (with viva-voce).

3. Certificate of Completion: Successful interns may receive a certificate of completion, detailing their achievements and skills acquired during the internship.

Semester-VI

MAJOR-12 MATH: 312: FUNDAMENTALS OF COMPLEX ANALYSIS
(4 CREDITS)

Course Objectives:

1. To learn about complex numbers and to analyze limit, continuity and differentiation of functions of complex variables.
2. To learn about analytic functions and construction of analytic functions.

	Course Outcome
CO 1	To understand Cauchy theorem and Cauchy integral formulas and apply these to evaluate complex contour integrals
CO 2	To represent analytic functions as Taylor and Laurent series
CO 3	To learn and classify singularities, poles and residues and evaluate complex integrals using the residue theorem

Unit I: (Sections 1 to 23)

Complex conjugates - Exponential form – Products and powers in Exponential form- Arguments of Products and Quotients- Roots of Complex numbers- Regions in the Complex plane- Functions of a complex variable- Mappings- Mappings by the exponential function- Limits- Theorems on Limits- Limits involving point at infinity- Continuity- Derivatives, Differentiation Formulas, Cauchy-Riemann Equations, Sufficient conditions for Differentiability- Polar Coordinates.

Unit II: (Sections 24 to 36)

Analytic functions, Examples, Harmonic functions, uniquely determined Analytic functions, The Exponential functions, The Logarithmic Function, Branches and derivatives of Logarithms, Some Identities involving Logarithm, Complex Exponents, Trigonometric Functions, and Hyperbolic Functions.

Unit III: (Sections 37 to 54)

Derivatives of functions w(t), Definite Integrals, Some Examples, Upper bounds for Moduli, Anti derivatives, Cauchy-Goursat Theorem (Statement only) , Multiply Connected Domains, Cauchy Integral Formula, An extension of the Cauchy Integral Formula, Some Consequences of the Extension, Liouville's Theorm and The Fundamental Theorem of Algebra, Maximum Modulus Principle.

Unit IV: (Sections 55 to 62)

Taylor's Series, Proof of Taylor's Theorem, Examples, Laurent Series, Proof of Laurent's Theorem, Examples.

Unit V: (Sections 68 to 77)

Isolated Singular Points, Residues, Cauchy's Residue Theorem, Residue at Infinity, The Three Types of Isolated Singular Points, Residues at Poles, Examples, Zeros of Analytic Functions, Zeros and Poles, Behavior of Functions Near Isolated Singular Points.

Text Book:

James Ward Brown and Ruel V. Churchill. Complex Variables and Applications,. Tata McGraw - Hill Education. 8th Edition, 2009.

Reference Books:

1. Erwin Kreyszig, Advanced Engineering Mathematics, John Wiley & Sons, 9th Edition, 2011
2. H.A. Priestley, Introduction to Complex Analysis, Second Edition, Oxford University Press, 2003
3. John B. Conway, Functions of One Complex Variable, Springer, ISE, 1973
4. Serge Lang, Complex Analysis, Springer Publishing Company, 4th Edition, 2009.
5. S. Ponnusamy, Foundations of Complex analysis, (2nd Edition), Narosa, 2011.
6. V. Karunakaran, Complex Analysis, (2nd Edition), Narosa 2005.

MAJOR-13 MATH: 313: INTRODUCTION TO LINEAR ALGEBRA
(4 CREDITS)

Course Objectives:

1. To understand vector spaces by its definition and examples.
2. To know how to represent a linear transformation by a matrix

	Course Outcome
CO 1	To learn elementary operations on Matrices and how to apply them to find the solutions of a system of equations
CO 2	To learn the properties of determinant of matrices
CO 3	To know about inner products and orthogonalization

Unit I: Section 1.2 to 1.6

Abstract Algebra Concepts – Groups- Subgroups- Fields- examples Vector space- Subspace-linear combinations and systems of linear equations- Linear dependence and linear independence- Basis and dimension.

Unit II: Section 2.1 to 2.5

Linear Transformations- Null spaces- Range spaces- Dimension theorem- Matrix representation of linear transformation- composition of linear transformations and Matrix multiplication- Invert ability and Isomorphism- The change of coordinate matrix.

Unit III: Section 3.1 to 3.4

Elementary matrix Operations and elementary matrices- The rank of a matrix and matrix inverses- systems of linear equations- Theory and computation

Unit IV: Section 4.1 to 4.4 and 5.1 to 5.2, 5.4

Determinants of order 2 and order n- propertie4s of determinants- Important facts about determinants- Eigen values and Eigen vectors- Diagonalizability- Invariant spaces and Cayley- Hamilton theorem.

Unit V: Section 6.1, 6.2

Inner products and norms- The Gram-Schmidt orthogonalisation process and orthogonal complements.

Text Book

Stephen H. Friedberg, Arnold J. Insel and Lawrence E. Spence, Linear Algebra, 4th Edition,
Printice Hall of India Pvt. Ltd., 2006

Reference Books

1. S. Kumaresan, Linear Algebra Geometric Approach, Prentice Hall of India Pvt. Ltd., 2000.
2. I. N. Herstein, Topics in Algebra, 2nd Edition, John Wiley & Sons, 2003.
3. David C. Lay, Linear Algebra and Applications (2nd Edition), Addison Wesley, 1997.
4. John B. Fraleigh, A First Course in Abstract algebra, (7th Edition), Pearson 2013.

MAJOR-14 MATH: 314: GRAPH THEORY (4 CREDITS)

Course Objectives:

1. To introduce the notion of graphs and the basic terminologies in graphs
2. To learn the concept of spanning trees, Cayley's formula and to introduce the concept of connectivity and edge connectivity of graphs

	Course Outcome
CO 1	To study about independent sets and matching and some of their properties
CO 2	To introduce the idea of Eularian and Hamiltonian graphs and their applications
CO 3	To study vertex coloring and edge coloring of graphs and some of the famous theorem in coloring problems

Unit I: (Sections 1.1-1.6, 4.1-4.3)
Graphs – Subgraphs – Isomorphism of graphs – Degrees of Vertices – Paths and Connectedness – Automorphism of a Simple Graph – Trees – Centers and Centroid.

Unit II: (Sections 3.1-3.3, 4.4,4.5)
Counting the Number of Spanning Trees – Cayley's Formula– Vertex Cuts and Edge Cuts – Connectivity and Edge-connectivity.

Unit III: (Sections 5.1-5.5)
Vertex Independent sets and Vertex Coverings – Edge-Independent Sets – Matchings and Factors –M-Augmenting Paths – Matchings in Bipartite Graphs – Halls Theorem on Bipartite graphs – Tutte's 1-Factor Theorem (without proof).

Unit IV: (Sections 6.1-6.3)
Eulerian graphs – Necessary and sufficient condition for Eulerian graphs – Hamiltonian graphs – Dirac theorem – Closure of a graph.

Unit V: (Sections 7.1,7.2,7.3.1, 7.6.2, 8.1-8.3)
Vertex Coloring – Chromatic Number –Critical Graphs – Brooks' Theorem – Edge Colorings of Graphs – Vizing's Theorem (without proof) – Planar and Nonplanar Graphs – Euler's Formula and its Consequences.

Text Book:-

1. R. Balakrishnan and K. Ranganathan, A Textbook of Graph Theory (Universitext), Second Edition, Springer New York 2012.

Reference Books:-

1. Bondy, J.A and Murthy, U.S.R, Graph Theory with Applications, Macmillan Press Ltd, New Delhi – (1976).Douglas B. West, Introduction to Graph Theory, Second Edition, PHI Learning Private Ltd, New Delhi-2011.
2. G. Chartrand, Linda Lesniak and Ping Zhang, Graphs and Digraphs, Fifth Edition, CRC press 2011.

MAJOR-15 MATH -315 LINEAR PROGRAMMING (4 CREDITS)

Course Objectives:

1 To learn the concept of LPP and Simplex Method
2 To learn the concept of Transportation and Assignment Model

	Course Outcome
CO 1	To study about Modeling with LPP and Simplex Method
CO 2	To study about Transportation Problem
CO 3	To study about Assignment problem and Duality

Unit – I: Modeling with Linear Programming (Chapter-2, Sections 2.1, 2.2, 2.4)
Two-Variable Linear Programming Model, Graphical LP Solution–Solution of a Maximization Model, Solution of a Minimization Model. Linear Programming Applications –Investment, Production Planning and Inventory Control, work force planning, Urban Planning,

Unit – II: The Simplex Method-I (Chapter-3, Sections 3.1, 3.2, 3.3)
LP model in Equation Form – Converting Inequalities into Equations with Nonnegative Righthand side, Dealing with Unrestricted variables. Transition from Graphical to Algebraic Solution, Iterative Nature of Simplex method, Computational Details of Simplex Method.

Unit – III: The Simplex Method-II (Chapter-3, Sections 3.4, 3.5,)
Artificial Starting Solution– Big-M-Method, Two-Phase Method. Special Cases – Degeneracy, Alternative Optima, Unbounded Solution, Infeasible Solution.

Unit – IV: Transportation Model (Chapter-5, Sections 5.1, 5.2, 5.3)
Definition of the Transportation Model, Nontraditional Transportation Models, The Transportation Algorithm, Determination of the Starting Solution, Iterative Computations of the Transportation Algorithm, Simplex Method Explanation of the Method of Multiplier.

Unit – V: Assignment Model and Duality (Chapter-5, Sections 5.4 & Chapter-7, Sections 7.4)
The Assignment Model, The Hungarian Method, Simplex Explanation of the Hungarian Method. Duality – Matrix Definition of the Dual Problem, Optimal Dual Problem.

Text Book:
1. Hamdy A Taha – Operations Research: An Introduction, 10th Edition, Pearson Prentice Hall, 2017.

Reference Books:
1. F. S. Hillier and G. J. Lieberman, *Introduction to Operations Research* (9th Edition),
Tata McGraw Hill, Singapore, 2009.
2. G. Hadley, *Linear Programming*, Narosa Publishing House, New Delhi, 2002.

Semester-VII

MAJOR-16 MATH 416: ADVANCED ALGEBRA
(4 CREDITS)

Course Objectives:

1. To learn isomorphism theorems group actions
2. To study about class equations and sylow theorems and its applications

	Course Outcome
CO 3	To know the direct product of groups and classifications of groups by applying the fundamental theorem finitely generated Groups
CO 4	To know the properties of Euclidean domain, Principal ideal domain and Unique factorization domain.
CO 5	To study the properties of Polynomial rings.

Unit I:
The isomorphism theorems -Composition Series - Transpositions and Alternating groups,

Unit II:
Group Actions: Group Actions and Permutation representations-Group acting on themselves by left multiplication-Cayley's theorem

Unit III:
Group acting on themselves by conjugation -The class equation- Automorphisms-The Sylow theorems- The simplicity of A_n.

Unit VI:
Direct and semi-direct products and abelian groups: Direct products- The fundamental theorem of finitely generated abelian groups.

Unit V:
Polynomial rings: Definitions and basic properties- Polynomial rings over fields- Polynomial rings that are unique factorization domains -Irreducible criteria.

Text Book:
David S. Dummit and Richard M. Foote, Abstract Algebra (Third Edition), John Wiley and sons, 2004.
Chapter 3 - Sections 3.3 to 3.5
Chapter 4 - Sections 4.1 to 4.6
Chapter 5 - Sections 5.1 and 5.2
Chapter 9 - Sections 9.1 to 9.4

Reference books
1 M. Artin: Algebra, Prentice-Hall of India, 1991.
2. I. N. Herstein: Topics in Algebra, Wiley Eastern Ltd., New Delhi, 1975.
3. N. Jacobson: Basic Algebra, Volumes I & II, W. H. Freeman, 1980.
4. S. Lang: Algebra, 3rd edition, Addison-Wesley, 1993.

MAJOR-17 MATH: 417 TOPOLOGY (4 CREDITS)

Course Objectives:

1. To introduce the notion of metric spaces and to characterize open sets in the real line
2. To study the concept of topological spaces and to study their properties like second count ability and separability

	Course Outcome
CO 1	To discuss in details about compactness of topological spaces and to prove the Tychnoff's theorem with some applications
CO 2	To study bout the equivalent versions of compactness in metric spaces
CO 3	To discuss some important theorems like Urysohn's lemma and the Tietze extension theorem. Also, we study about connected spaces

Unit I: (Revision of Sections 1-3, Section 4-8, 9-12)
Revision of sets - Functions - Product of sets – Relations – Countable sets – Uncountable sets – Partially ordered sets and lattices – Metric spaces – Definition and examples – Open sets and closed sets in metric spaces – Open subsets of real line.

Unit II: (Sections 16, 17 and 18)
Topological spaces -- Definitions and examples - Closure and related concepts – Open bases and open sub bases – Separability and second count ability -Lindloff's Theorem

Unit III: (Sections 21 – 23)
Compactness – Basic results -- Continuous maps on compact sets - Characterization of compactness by basic and sub basic open covers – Tychon off's theorem - Generalized heine – Bore theorem.

Unit IV: (Sections 24,26)
Compactness for metric spaces – Sequential compactness - Lebesgue covering lemma - Sequential compactness and compactness coincide on metric spaces - T_1spaces - Hausdorff spaces.

Unit V: (Sections 27,28,31,32)
Completely regular spaces and normal spaces – Urysohn's lemma and Tietze extension theorem- –Connected spaces – Components of a space.

Text Book

G.F.Simmons, an Introduction to Topology and Modern Analysis, McGraw-Hill Kogakusha, Tokyo, 1963

Reference Books

1. J. R. Munkres, Toplogy, Pearson Education Inc., Second Edition, 2000.
2. Stephen Willard, General Topology, Dover Publication 2004.
3. J. Dugundgi, Toplogy, Allyn and Bacon, Boston, 1966.
4. Fred.H. Croom, Principles of Topology, Dover publications, 2016.

MAJOR-18 **(4 CREDITS)**

MATH: 418: DIFFERENTIAL EQUATIONS AND SPECIAL FUNCTIONS

Course Objectives:

1. To study the qualities properties of ordinary differential equations.
2. To study the hypergeometric functions, Bessel functions and Legendre polynomials which arising as solution of ODEs

	Course Outcome
CO 1	To study the series solutions of ODEs,
CO 2	To study the existence and uniqueness of solutions of first order ODEs.

Unit I: [Chapter-4, Sections: 25, Chapter-5, Sections: 26, 27, 28, 29, 30 & Chapter -7, Sections: 40 of [1]]
Qualitative properties of solutions – The Sturm Separation Theorem, The Sturm comparison theorem– Eigen values and Eigen functions and vibrating string. Series solutions of first order equations – Second order linear equations – Ordinary points - Regular singular points

Unit II: [Chapter-5, Sections: 31 of [1] & Chapters: 4 & 7 of [2]]
Gauss Hypergeometric equations. Gauss's hypergeometric and Confluent hypergeometric functions, integral representations, differentiation formulas, transformation formulas, summations formulas.

Unit III: [Chapter-8, Sections: 44, 45, 46 47 of [1]]
Legendre polynomials – Properties of Legendre polynomials – Bessel functions- The Gamma function - Properties of Bessel Function.

Unit IV: [Chapter-10, Sections: 55, 56 of [1]]
Linear systems – Homogeneous linear system with constant coefficients.

Unit V: [Chapter-13, Sections: 68, 69 of [1]]
The existence and uniqueness of solutions – The method of successive approximations – Picards's theorem.

Text Book

1) G. F. Simmons, Differential Equations with Applications and Historical Notes, 2nd Edition, McGraw Hill Education(India) Company, 2003.
Sections: 22-30, 32-35, 37-38 and 55-56.
2) E. D. Rainville, Special *functions*, Macmillan, New York, 1960.

References

1. Earl Coddington and Norman Levinson, Theory of ordinary Differential equations, TATA McGraw Hill, 2017.
2. N. M. Temme, *Special functions: An introduction to the classical functions of mathematical physics*, John Wiley& Sons, New York, 1996.

Semester-VIII

MAJOR-19 MATH: 419: ADVANCED REAL ANALYSIS (4 CREDITS)

Course Objectives:

1. To study about functions of bounded variation, double sequence, double series and infinite products
2. To study about convergence of sequences and series of functions and their properties

	Course Outcome
CO 1	To prove some famous theorems like Weierstrass approximation theorem and stone Weierstrass theorem
CO 2	To study about differentiability of functions of several variables and to prove the contraction mapping theorem.
CO 3	To prove the important theorems- The inverse function and the implicit function theorem

Unit I:(Chapter:6 and Sections: 8.20 to 8.23, 8.26 and8.27 of [2])

Functions of bounded variation - Double sequences - Double series - Rearrangement theorem for double series- A sufficient condition for the equality of iterated series.

Unit II: (Chapter: 7 of [1], Subsections 7.1 to 7.25)

Sequence and Series of functions - Examples - Uniform convergence and Continuity - Uniform convergence and Integration - Uniform convergence and Differentiation - Double sequences and series - Iterated limits- Equicontinuous Families of Functions - Arzela – Ascoli Theorem

Unit III:(Chapter: 7 of [1] subsections: 7.26 to7.33 and chapter 8 of [1])

The Weierstrauss theorem for algebraic polynomials- The Stone - Weierstrauss Theorem - Power Series - The Exponential and Logarithmic Functions - The Trigonometric Functions - Fourier Series - The Weierstrauss theorem for the Trigonometric polynomials.

Unit IV: (Chapter:9 of [1], Subsections: 9.6 to 9.23)

Functions of Several Variables - Linear Transformation - Differentiation - The Contraction Principle.

Unit V:(Chapter: 9 of [1], Subsections:9.24 to 9.38)

The inverse function Theorem - The implicit Function Theorem - The Rank Theorem – Determinants.

Text Books

1. Walter Rudin, Principles of Mathematical Analysis- McGraw Hill International Editions, Mathematics series, 1976.
2. Apostol, Mathematical Analysis, Narosa Publishing House, Indian edition,2002.

Reference Books

1. Patrick M. Fitzpatrick Advanced Calculus, Amer. MATH. Soc. Pine and Applied Undergraduate Texts, Indian Edition, 2009.
2. Kenneth A. Ross, Elementary Analysis, The Theory of Calculus, Springer-Verlag,1980.
3. N.L.Carothers, *Real Analysis*, Cambridge University Press(2000)
4. G.F.Simmons, Introduction to Topology and Modern Analysis, McGraw Hill, 2017.

MAJOR-20 MATH 420: ADVANCED LINEAR ALGEBRA
(4 CREDITS)

Course Objectives:

1. To understand linear transformations Characteristic roots- Similarity of linear transformations, Invariant subspaces and matrices.
2. To understand triangular forms- Nilpotent transformations.

	Course Outcome
CO 1	To understand Jordan forms- Fundamental theorem on modules over PID.
CO 2	To understand Rational canonical form- Trace- Transpose & Determinants.
CO 3	To understand Hermitian - Unitary and Normal transformations - Real quadratic forms.

Unit I: Sections – 6.1,6.2, 6.3 [1] and 13.1-13.2 [2]
Field theory: Splitting fields and Algebraic closures. The Algebra of linear transformations-Characteristic roots- Similarity of linear transformations.

Unit II: Sections – 6.4 and 6.5 [1]
Invariant subspaces and matrices. Reduction to triangular forms.

Unit III: Sections – 6.6 and 4.5 [1]
Nilpotent transformations - Index of nil potency and invariant of nilpotent transformation. Jordan blocks and Jordan forms-

Unit IV: Sections - 6.7, 6.8 and 6.9 [1]
Modules - Cyclic modules - Fundamental theorem on modules over PID- Rational canonical form- Trace- Transpose and Determinants.

Unit V: Sections – 6.10 and 6.11 [1]
Hermitian - Unitary and Normal transformations - Real quadratic forms.

Text Book: 1. I.N. Herstein, Topics in Algebra, Wiley Eastern Ltd., New Delhi, 1975.
2. Abstract Algebra (Third Edition) by David S. Dummit and Richard M. Foote,
(Sections 13.1-13.2)

Reference Books

1. M. Artin, Algebra, Prentice-Hall of India, 1991
2. N. Jacobson, Basic Algebra, Volumes I & II, W. H. Freeman, 1980.
3. S. Lang, Algebra, 3rd edition, Addison-Wesley, 1993
4. P.B. Bhattacharya, S.K. Jain and S.R. Nagpaul, Basic Abstract Algebra (2nd Edition)Cambridge University Press, Indian edition, 1997
5. Kenneth Hoffmann and Ray Kunze, Linear Algebra, (Second edition), Pearson, 2015
6. S. Friedberg, A. Insel and L. Spence, Linear Algebra, (4^{th} Edition) Pearson, 2015.

Minor-9 : MATH 427 : COMPLEX ANALYSIS (4 CREDITS)

Course Objectives:

1. To Learn and understand about the properties of Line integral and Zeros and Poles.
2. To discuss about the theorems on Series expansion, Residue and Factorization.

	Course Outcome
CO 1	To discuss about the Line integrals, Cauchy theorem and Cauchy integral formula
CO 2	To study about the Zeros and Poles of functions and the Maximum principle
CO 3	To study about the Calculus of Residues, Evaluation of Definite Integrals and Harmonic functions
CO 4	To study about Series Expansions and Partial Fractions and Factorization
CO 5	To study the Jenson Formula-Hadamard' Theorem and the Riemann Zeta Function

Unit I: [Chapter-4, Sections: 1 and 2]

A quick review of analytic function – Cauchy-Riemann equations. Line integrals-Cauchy's theorem for a Rectangle-Cauchy's theorem in a Disc-Cauchy's integral formula-Higher derivatives

Unit II: [Chapter-4, Sections: 3 and 4].

Local properties of Analytical Functions-Removable Singularities, Zeros and poles-The Maximum principle- The general form of Cauchy's theorem.

Unit III: [Chapter-4, Sections:5 and 6].

The Calculus of Residues-The Residue Theorem- The Argument principle-Evaluation of Definite Integrals. Harmonic functions- Poisson's formula- Schwarz's theorem- The Reflection Principle.

Unit IV: [Chapter-5, Sections: 1 and 2].

Power Series Expansions-Weierstrass's Theorem-The Taylor series-The Laurent's series. Partial Fractions and Factorization-Infinite Product-The Gamma function-Stirling formula.

Unit V: [Chapter-5, Sections: 3 and 4, Chapter-8, Sections: 1]

Entire Functions-Jenson Formula-Hadamard' Theorem. The Riemann Zeta Function-Extension of Riemann Zeta function to the Whole Plane-The Functional Equation-The Zeros of the Zeta Function. Analytic Continuation.

Text Book: L.V. Ahlfors, Complex analysis, Third Edition, McGraw Hill Book Company,1979.

References:

1. John. B. Conway, Functions of one Complex Variable, Second Edition, Narosa Publishing House, 2002.
2. B. C. Palka, An Introduction to the Complex function Theory, Springer, 1991.
3. H.A. Priestley, Introduction to Complex Analysis, Second Edition, Oxford University Press, 2003.
4. S. Ponnusamy, Foundations of Complex analysis, (2nd Edition), Narosa, 2011
5. Donald Sarason, Notes on Complex Function Theory, Hindustan Book agency, 1994.

Minor-10 : MATH 428: MEASURE AND INTEGRATION
(4 CREDITS)

Course Objectives:

1. Motivation to Lebesgue measure theory and the introduction of Lebesgue outer measure
2. To study about Lebesgue measurable sets and their properties.

	Course Outcome
CO 1	To introduce Lebesgue measurable functions and to prove important theorems like Egoroff's theorem and Lusin's theorem
CO 2	To study about the Lebesgue integrable functions and to prove some important convergence theorems
CO 3	To study about absolutely continuous functions and to prove the fundamental theorem of calculus for Lebesgue integral

Unit I: (Sections: 3.1, 3.2, 3.3, 3.6 of [1] and 2.1, 2.2 of [2])

Motivation to Lebesgue Measure Theory – General extension Theory – Algebra of sets – Examples – Finitely/Countably additive set functions – Ulam's Theorem – Continuity from below/above of measures – The Lebesgue outer measure m^* - Examples – Properties.

Unit II: (Sections: 2.3, 2.4, 2.5, 2.6, 2.7 of [2])

Lebesgue measurable sets – Examples – The set of all Lebesgue measurable sets M is an algebra - $m^*$is finitely additive over M – M is a sigma algebra – m^* is a measure on M – Outer and inner approximation of Lebesgue measurable sets by open and closed sets respectively –Continuity of the Lebesgue measure – Example of a nonmeasurable set – The Cantor Lebesgue function.

Unit III: (Sections: 3.1, 3.2, 3.3 of [2])

Lebesgue measurable functions – Examples – Pointwise limit of sequence of measurable functions – Simple functions – The simple approximation Lemma – The simple approximation Theorem – Egoroff's Theorem – Lusin's Theorem.

Unit IV: (Sections: 4.2, 4.3, 4.4, 4.5,5.3 of [2])

The Lebesgue integral of a simple function – The Lebesgue integral of a bounded measurable function over a set of finite measure – Properties – The Bounded Convergence Theorem - The Lebesgue integral of a nonnegative measurable function – Properties – Chebychev's inequality – Fatou's Lemma – Monotony Convergence Theorem – The general Lebesgue integral – The Lebesgue dominated Convergence Theorem – Characterization of Riemann integrable functions – Improper Riemann integrals and their Lebesgue integrals.

Unit V: (Sections: 6.1, 6.2, 6.3(upto6.3.6) of [1])

Review of functions of bounded variation –Absolutely continuous functions – Lebesgue's Theorem on differentiability of monotony functions – The Lebesgue singular function – Fundamental Theorem of Calculus [I and II] for the Lebesgue integral

Text Books:

1. Inder K. Rana, *An Introduction to Measure Theory and Integration ,(2e)*, Narosa (2007)
2. H. L. Roylan, P. M. Fitzpatrick, *Real Analysis –Fourth Edition,* Prentice Hall of India (2013).

Reference books:

1. De Barra.G, *Measure Theory and Integration,* 2e, New Age International Publishers (2013).
2. Howard J.Wilcox, *An Introduction to Lebesgue Integration and Fourier Series*, Dover (1995).
3. Paul R. Halmos, *Measure Theory,* Springer (1976).
4. N.L.Carothers, *Real Analysis,* Cambridge University Press(2000).
5. C.D. Aliprantis and O.Burkinshaw, *Principles of Real Analysis*,3e, Academic Press (Elsevier).

LIST OF MINORS FOR 4th Year (ANNEXURE - I)

Minor: MATH 421: CRYPTOGRAPHY (4 CREDITS)

Course Objectives:

1. To know various kinds of classical cryptography
2. To know about data encryption standards

	Course Outcome
CO 1	To know about public key crypto system
CO 2	To learn various methods of digital signatures
CO 3	To learn about hashing and its applications

Unit I:

Introduction: Overview of course- Classical cryptography [parts of Chapter 1].

Unit II:

Secret Key Encryption: Perfect Secrecy - One time pads [Chapter 2.1], Stream ciphers and the Data Encryption Standard (DES) [Chapter 3 (excluding 3.6)], The Advanced Encryption Standard (AES) - adopted September 2000.

Unit III:

Public Key Encryption: Factoring and the RSA encryption [Chapter 4.1 -4.4], Discrete log- Diffie-Hellman Key Exchange [Chapter 8.4 (only pages 270-273)].

Unit IV:

ElGamal encryption [Chapter 5 (only pages 162-164)] , Digital Signatures [Chapter 6 (excluding 6.5 - 6.6)], One-time signatures- Rabin and ElGamal signatures schemes- Digital Signature Standard (DSS).

Unit V:

Hashing: Motivation and applications- Cryptographically Secure Hashing. [Chapter 7.1-7.3,7.6], Message Authentication Codes (MAC)- HMAC- Network Security - Secure Socket Layer (SSL)- I Psec.,Secret Sharing- Definition. Shamir's threshold scheme [Chapter 11.1], Visual secret sharing schemes.

Text Book

D. R. Stinson,s Cryptography, Theory and Practice, CRC Press, 1995.

Reference Books

1. Richard A. Mollin, An Introduction to Cryptography, Chapman & Hall / CRC, Boca Raton, 2000.

2. Dominic Walsh, Codes and Cryptography, Oxford Science Publications, Clarendon Press, Oxford, 1988.

Minor: **MATH 422: NUMERICAL ANALYSIS (4 CREDITS)**

Course Objectives:

To find the roots using numerical methods.

To apply numerical techniques for solving systems of equations.

	Course Outcome
CO 1	To learn various interpolation techniques.
CO 2	To know numerical integration.
CO 3	Solve initial and boundary value problems in differential equations using numerical methods.

Unit I: Nonlinear Equations in One Variable:

Fixed point iterative method – convergence Criterion -Aitken's $\Delta 2$- process - Sturm sequence method to identify the number of real roots – Newton - Raphson's methods convergence criterion Ramanujan's Method - Bairstow's Method.

Unit II: Linear and Nonlinear System of Equations:

Gauss eliminations with pivotal strategy jacobi and Gauss Seidel Itervative Methods with convergence criterion. LU - decomposition methods – (Crout's, Choleky and DeLittle methods) – consistency and ill conditioned system of equations - Tri-diagonal system of equations – Thomas algorithm. Iterative methods for Nonlinear system of equations, Newton raphson, Quasi newton and Over relaxation methods for Nonlinear system of equations.

Unit III: Interpolation:

Lagrange- Hermite- Cubic-spline's (Natural, Not a Knot and Clamped)- with uniqueness and error term, for polynomial interpolation- Bivariate interpolation- Orthogonal polynomials Grams SchmidthOrthogoralization procedure and least square- Chebyshev and Rational function approximation.

Unit IV: Numerical Integration:

Gaussian quadrature, Gauss-Legendre- Gauss-Chebeshev formulas- Gauss Leguree, Gauss Hermite and Spline intergation – Integration over rectangular and general quadrilateral areas and multiple integration with variable limits.

Unit V: Numerical solution of ordinary differential equations:

Initial value problems- Picard's and Taylor series methods – Euler's Method- Higher order Taylor methods - Modified Euler's method - RungeKutta methods of second and fourth order – Multistep method - The Adams - Moulton method - stability - (Convergence and Truncation error for the above methods). Boundary - Value problems – Second order finite difference and cubic spline methods.

Text books

1. M. K. Jain, S. R. K. Iyengar and R.K. Jain, Numerical methods for scientific and Engineering computation, Wiley Eastern Ltd. 1993, Third Edition.
2. C.F. Gerald and P.O. Wheatley, Applied Numerical Methods, Low- priced edition, Pearson Education Asia 2002, Sixth Edition.
3. M.K. Jain, Numerical solution of differential equations, Wiley Eastern (1979), Second Edition.

Reference books

1. S.C. Chapra and P.C. Raymond, Numerical Methods for Engineers, Tata McGraw Hill, New Delhi,2000
2. S.S. Sastry , Introductory methods of Numerical analysis, Prentice - Hall of India, New Delhi, 1998.
3. Kendall E.Atkinson, An Introduction to Numerical Analysis (2nd Edition), Wiley, 2008.

Minor: MATH 423: NUMBERS THEORY (4 CREDITS)

Course Objectives:

1. To study primes
2. To study solution for congruences

	Course Outcome
CO 1	To understand Quadratic residues
CO 2	To study arithmetic functions
CO 3	To study continued fraction and its convergences

Unit II: Section : 1.1-1.3
Divisibility: Introduction -Divisibility- Primes.

Unit II: Section : 2.1-2.11
Solution of congruences – Congruences of higher degree – prime power moduli.

Unit III: Section :3.1-3.3
Quadratic Residues, Quadratic reciprocity law, Jacobi Symbol.

Unit IV: Section :4.1-4.3
Arithmetic functions-Recurrence functions, Mobious Inversion Formula, Irrational numbers, Irrationality of nth root of N, e and pi.

Unit V: Section : 5.6-5.11
Continued fractions and its convergence, representation of an irrational number by an infinite continued fraction. Some special quadratic surds.

Text Book

Treatment as in I. Niven, H.S. Zuckerman and H.L. Montgomery – An Introduction to the Theory of Numbers, New York, John Wiley and Sons, Inc., 2004, 5th Ed.

Books for Reference:

1. **T.M. Apostol** – Introduction to Analytic Number Theory, Narosa Publishing House, New Delhi.
2. **G.H. Hardy and E.M. Wright-** An Introduction to the Theory of Numbers, Oxford University Press, 1979, 5th Ed.

Minor: MATH 424: CALCULUS OF VARIATIONS (4 CREDITS)

Course Objectives:

1. To learn about functionals and solving related variational problems by Euler's equation
2. To understand and solve the variational problems functionals depending on higher order derivatives

	Course Outcome
CO 1	To study about the general variational of a functional and the Weierstrass Erdmann conditions
CO 2	To study and understand about canonical form of Euler equations and other transformations, Noether's Theorem and conservation laws
CO 3	To learn about second variation and Legendre conditions of a functional

Unit I:

Functionals- some simple variational problems-The variation of a functional- A necessary condition for an extremum-The simplest variational problem-Euler's equation-The case of several variables-A simple variable end point problem-The variational derivative-Invariance of Euler's equation.*[Chapter-1]*

Unit II:

The fixed end point problem for n-unknown functions - Variational problem in parametric form- Functionals depending on higher order derivatives-Variational problems with subsidiary conditions. *[Chapter-2]*

Unit III:

The general variational of a functional- derivation of the basic formula- End points lying on two given curves or surfaces- Broken extremals- The Weierstrass Erdmann conditions. *[Chapter-3]*

Unit IV:

The canonical form of Euler equations- First integrals of the Euler equations- The Legendre transformation- Canonical transformations- Noether's Theorem- The principle of least action- Conservation laws- The Hamilton Jacobi equation-Jacobi theorem.*[Chapter-4]*

Unit V:

The second variation of a functional- The formula for the second variation, Legendre conditions- Sufficient conditions for a weak extremum. *[Chapter-5]*

Text Book:

I.M. Gelfand and S.V.Fomin, *Calculus of Variations*, Dover Publications, 2000.

Reference Books:

1. A.S. Gupta, *Calculus of Variations with Applications*, Prentice-Hall of India, 2008.
2. M.L. Krasnov, G.I. Makarenko and A.I. Kiselev, *Problems and Exercises in the Calculus of Variations*, Mir Publishers, Moscow 1975.

Minor: MATH- 425- GALOIS THEORY (4 credits)

Objectives:
To study Polynomial rings, Field theory, Splitting fields and Algebraic closures, Galois Theory and Composite extension and simple extensions.

	Course Outcome
CO 1	To study about the various extension fields and splitting field
CO 2	To study and understand about Solvable by radicals
CO 3	To learn about finite and cyclotomic fields and Wedderburn Theorem

Unit I: Field theory: Basic theory of field extensions-Algebraic Extensions.

Unit II: Splitting fields and Algebraic closures - Separable and inseparable extensions - Cyclotomic polynomials and extensions.

Unit III: Galois Theory: Basic definitions- The fundamental theorem of Galois Theory - Solvable by radicals.

Unit IV: - Galois groups over the rationales. Finite Fields- Wedderburn's theorem(First proof only)

Unit V: Classical straightedge and compass constructions, Cyclotomic extensions and Abelian extensions, Galois group of polynomials.

Text Book:
1. Abstract Algebra (Second Edition) by David S. Dummit and Richard M. Foote, Wiley Student Edition (1999) for Units I to III, (Chapter 13), (Sections 14.1 to 14.3 and 14.5-14.6).

2. Topics in Algebra by I.N. Herstin (Section 5.6 - 5.8), and (Section 7.1 -7.2).

Reference books
1. M. Artin: Algebra, Prentice-Hall of India, 1991.
2. N.Jacobson: Basic Algebra, Volumes I & II, W.H.Freeman, 1980.
3. S.Lang: Algebra, 3rd edition, Addison-Wesley, 1993.

Minor: MATH 426: LATTICE THEORY (4 CREDITS)

Course Objectives:

1. To explain the basic theory of partially ordered sets
2. To elaborate on basics of well-ordered sets

	Course Outcome
CO 1	To apply key properties of Lattices
CO 2	To categorize the important types of lattices
CO 3	To discuss the Boolean algebras with their applications

Unit I: Partially Ordered Sets: (Chapter: 1**)**
Basic Definitions – Duality – Monotone Maps – Down-Sets and the Down Map – Height and Graded Posets – Chain Conditions – Chain Conditions and Finiteness – Dilworth's Theorem – Symmetric and Transitive Closures – The Poset of Partial Orders.

Unit II: Well- Ordered Sets: (Chapter: 2**)**
Well-Ordered Sets – Ordinal Numbers – Transfinite Induction – Cardinal Numbers – Ordinal and Cardinal Arithmetic – Complete Posets.

Unit III: Lattices: (Chapter: 3**)**
Closure and Inheritance – Semilattices – Arbitrary Meets Equivalent to Arbitrary Joins – Lattices – Meet-Structures and Closure Operators – Properties of Lattices – Irreducible Elements – Completeness – Sublattices – Denseness – Lattice Homomorphisms – Ideals and Filters – Prime and Maximal Ideals.

Unit IV: Modular and Distributive Lattices: (Chapter: 4**)**
Quadrilaterals – The definitions and Examples – Characterizations – Modularity and Semi modularity – Partition Lattices and Representations – Distributive Lattices.

Unit V:Boolean Algebras: **(**Chapter: 5**)**
Boolean Lattices – Boolean Algebras – Boolean Rings – Boolean Homomorphisms – Characterizing Boolean Lattices – Complete and Infinite Distributivity

Text Book:-

1. Steven Roman, Lattices and Ordered Sets, Springer Science, 2008.

   Chapters: 1,2,3,4,and 5.

Reference Books:-

1. Garrett Birkhoff, Lattice Theory, American Mathematical Society, Colloquim Publications, 1948.

Semester-IX

MAJOR-21 HARD CORE: MATH 521 - FUNCTIONAL ANALYSIS
(4 Credits)

Objectives:

To study Normed Linear Spaces, Continuity, Equivalent norms, Hahn-Banach theorem for real vector spaces, Closed and open maps, Separable Hilbert spaces, Orthogonal projections

	Course Outcome	**Level**
CO 1	explain the concepts of normed linear space (NLS), continuity of alinear map, Lp-space, Banach, Hilbert spaces, four pillars	Remember & Understand
CO 2	demonstrate the convergence in the different types of spaces	Apply
CO 3	analyze the properties of different types NLS	Analyze
CO 4	determine the linear functional in terms orthonormal basis	Evaluate
CO 5	Obtain the open mapping theorem from closed graph theorem and vice-versa	Create

Unit-I Sections: 1.2.3, 1.2.5, 2.1, 2.1.1, 2.1.2, 2.1.4

Review of linear spaces – Linear functionals – hyperspaces – projections – Cauchy Schwarz inequality – Holder's inequality –Minkowski inequality – Normed linear spaces – Definition and examples – Basic properties – Semi norms and quotient spaces – product spaces and the graph norm.

Unit-II Sections:3.1, 3.1.1, 3.2, 3.2.1, 3.4.1, 2.2, 2.2.1, 2.2.2, 2.2.3, 2.4

Bounded linear Maps – Properties – Norm of a bounded linear Map – Banach spaces – Completeness of $l_p(1 \leq p \leq \infty), L_p[a,b], C[a,b], BV[a,b]$ – Completeness of the space of all bounded linear Maps – The completeness of the quotient space – The completion of a normed linearspace – Completeness and absolutely convergent series – Finite dimensional normed linear spaces – Riesz Lemma.

Unit-III Sections: 5.1, 5.2, 5.3, 5.4, 3.4, 6.1

The Hahn – Banach Extension Theorem anditscorollaries – The Hahn Banach Separation Theorem – Convergence of sequence of operators – The uniform Boundedness principle – The Banach Steinhauss Theorem – Weakly bounded sets – Schauder basis and separability.

Unit-IV Sections: 7.1, 7.2, 7.3, 8.1, 8.1.2

The closed graph Theorem – The bounded inverse theorem – The open mapping Theorem – The dual of $l_p(1 \leq p < \infty)$, the dual of $(C_{00}, ||.||_p)$ when $(1 \leq p < \infty)$ - The dual of $(C, \|.\|_\infty)$.

Unit-V Sections: 2.1.5, 4.1, 4.2, 4.3, 4.4, 2.5, 2.6, 3.3

Inner product spaces – Orthonormal sets –Gram Schmidt Orthogonalization process – Bessel's inequality – Hilbert spaces - Parseval's Theorem – Example of a nonseparable Hilbert space – Best approximation Theorems – Projection Theorem – Riesz Fischer Theorem – The Riesz representation Theorem.

Text Book:

1. M.Thamban Nair, *Functional Analysis: A First Course*, Prentice Hall of India, 2002.

Reference Books:

1. Joseph Muscat, *Functional Analysis*, Springer(2008).
2. BalmohanV.Limaye, *Functional Analysis*, New Age International Publishers (2014).
3. Erwin Kreyszig, *Introductory Functional Analysis with Applications*, John Wiley(2007).
4. Martin Schecter, *Principle of Functional Analysis*, American Mathematical Society (2009)
5. BelaBollobas, *Linear Analysis:An Introductory Course*,2e, Cambridge Univ. Press (1999).
6. Bryan P. Rynne and Martin.AYoungson, *Linear Functional Analysis*, Springer (2008).

MAJOR-22 MATH 522: PARTIAL DIFFERENTIAL EQUATIONS
(4 Credits)

Objectives:
To study first order PDEs, Non-linear first order PDEs, Classification of second order PDEs, Wave Equations**,** Laplace equations, Heat Equations.

	Course Outcome	Level
CO 1	understand the relation between the theory and modelling in the problems arising in various fields, such as, economics, finance, applied sciences and etc	Remember Understand
CO 2	Enhance their mathematical understanding in representing solutions of partial differential equations.	Apply
CO 3	classify the partial differential equations and transform into canonical form	Analyze
CO 4	determine the solution representation for the three important classes of PDEs, such as Laplace, Heat and wave equation by various methods.	Evaluate
CO 5	Formulate fundamentals of partial differential equations, like Green's function, maximum principles, Cauchy problem, to take a research career in the area of partial differential equations	Create

Unit – I: First Order PDEs

Surfaces and their Normals, Curves and tangents - Genesis of first order PDE- Classification of Integrals- Linear equations of first Order - Integral surface passing through a curve – Cauchy problem for first order PDE – Orthogonal Surfaces.

Non-linear first order PDEs : Compatible systems- Solutions of Quasi linear equations

Charpit's method- Special Types of Charpits Method, -Integral surfaces through a given curve-The Cauchy problem for Quasi Linear case and nonlinear first order PDEs.

Unit – II: Second Order PDEs

Genesis of Second order PDEs- Classification of second order PDEs- Canonical forms of Hyperbolic- Elliptic and parabolic type PDEs, Linear PDE with constant coefficients – Method of finding CF and particular integral- Homogeneous linear PDE

Unit – III **Hyperbolic PDEs / Wave Equation**

Derivation of One –dimensional wave equations- Initial Value Problem – D'Alembert Solution, Method of separation of variables, Forced Vibration, Solution of non-homogeneous equation Uniqueness of solution of wave equation.

Unit – IV: Elliptic PDEs/Laplace Equations

Derivation of Laplace equations & poisson equation- Boundary value problems- Properties of Harmonic functions- Spherical Mean, Mean value theorem- Maximum and minimum principles- Separation of variables- Dirichlet problem and Neumann problems for a rectangle and circle (Upto 2.10 in Text Book 1). Application - Irrotational Flow of an Incompressible Fluid (Section 2.13)

Unit – V: Heat Equations

Diffusion Equation, Boundary Conditions - Elementary solution- Solution by separation of variables- Classification in n-variables- Families of equipotential surfaces

Text Books

1. K. Shankara Rao, Introduction to Partial Differential Equations, PHI Publications, 3rd Edition. 2011.
2. T. Amarnath, An Elementary Course in Partial Differential Equations, Narosa Publishing House, 2010.

Reference Books

1. I. N. Sneddon, Elements of Partial DifferentiaI Equations, McGraw Hill, International Edition, 1986.
2. F. John, Partial Differential Equations, Springer Verlag, 1975.
3. Lawrence C. Evans, Partial Differential Equations, Graduate Studies in Mathematics, 1998.

LIST OF MINORS FOR 5th Year (ANNEXURE - II)

Minor:12-19 MATH 531: DIFFERENTIAL GEOMETRY (4 CREDITS)

Course Objectives:

1. To learn about parametric curves, level curves and the notion of curvation of plane curves
2. To study about the properties of space curves, Serret Frenet equations and the four vertex theorem

	Course Outcome
CO 1	To study about surfaces, quadratic surfaces, triple orthogonal systems
CO 2	To calculate the length of curves on surfaces and surface area
CO 3	To study about the normal and principle curvature of curves on a surface and Euler's theorem

Unit I: [Sections: 1.1 to 1.4 and Sections 2.1,2. 2.]

Curves- arc length- Reparametrization-Level curves - Curvature - Plane curves.

Unit II: [Sections 2.3 and Sections 3.1 to 3.3.]

Space curves-Torsion- Serret Frenet equations- Simple closed curves- The Isoperimetric Inequality- The Four vertex Theorem.

Unit III: [Sections 4.1 to 4.7]

Smooth surface- Tangents, normal and orient ability- Examples of surfaces- Quadratic surfaces- Triple orthogonal systems- Applications of Inverse function theorem

Unit IV: [Sections: 5.1 to 5.5]

Lengths of curves on surfacesa- First fundamental form- Isometries of surfaces- Conformal mapping of surfaces- Surface area- Equiareal maps and a theorem of Archimedes.

Unit V: [Sections: 6.1 to 6.4]

The Second Fundamental form- The Curvature of curves on a surface- The normal and principal curvature- Euler's theorem- The geometric interpretation of principal curvatures.

Text Book:

1. Andrew Pressley, *Elementary Differential Geometry*, Springer, 2004.

Reference Books:

1. Christian Bar, *Elementary Differential Geometry*, Cambridge University Press, 2011.
2. Thomas F. Banchoff and Stephen T. Lovett, *Differential Geometry of Curves and Surfaces*, A.K Peters/CRC press, 2010.
3. W. Klingenberg, *A course in Differential Geometry*, Springer-Verlag, New York, 1978.

Minor:12-19 MATH 532: NUMERICAL ANALYSIS FOR ORDINARY DIFFERENTIAL EQUATIONS (4 Credits)

Objectives:
To study various numerical methods to solve ordinary differential equations such as Euler's method, Gaussion quadrature and Error Control.

Unit-I
Euler's method - Trapezoidal rule - Theta method.

Unit-II
Adams - Bashforth method - Order and convergence - Backward differentiation formula.

Unit-III
Gaussion quadrature - Explicit Runge - Kutta scheme - Implicit Runge Kutta scheme - Collocation.

Unit-IV
Stiff equations - Linear stability domain and A- Stability -- A-stability of RK and multistep methods.

Unit-V
Error Control - Milne Device - Embedded Runge Kutta method.

Text Book

1. Arieh Iserles, A First Course in the Numerical Analysis of Differential Equations, Cambridge University press, 2nd edition, 2008.

Reference Books:

1. Richard L. Burden and J.Douglas faires, Numerical Analysis(9th Edition), Cengage Learning India, 2012.

Minor:12-19 MATH 533: q-SERIES IN NUMBER THEORY
(4 CREDITS)

Course Objectives:

1. To understand basic hypergeometric series
2. To study unilateral series

	Course Outcome
CO 1	To study bilateral series
CO 2	To study theta function identities
CO 3	To study classical theta functions

Unit I

Introduction to Basic hyper Geometric series- Bionomial theorem- q- bionomial theorem Heine's Trasformation formula- Jackson transformation formula

Unit II

Jacobi's triple product identity and its applications and Quintuple product identity and Gaussian polynomials.

Unit III

Bilateral Series- Ramanujan I Ψ 1summation and related identities- Ramanujan theta function identities involving Lambert series.

Unit IV

q- series and theta functions Entries 18 to 30 Chapter 16 of Ramnujan's notebook.

Unit V

Classical theta functions to hypergeometric series and its applications.

Text Book

1. Gasper and Rahman, Basic hyper geometric series, Cambridge University press 1990.(Unit I-III)
2. BC Berndt Ramanujans notebooks Part II Springer Verlag New York 1991.(Unit IV-V)

Minor: 12-19 MATH 534: INTEGRAL TRANSFORMS AND THEIR APPLICATIONS (4 CREDITS)

Course Objectives:

1 To learn and understand Laplace and Hankel transforms with properties and Applications.
2 To learn and understand Mellin and Z transform with properties and Applications

	Course Outcome
CO 1	To study about Laplace transform and Inverse Laplace transform
CO 2	To study about Applications of Laplace transform
CO 3	To study Hankel transform with properties and to solve the PDE
CO 4	To study Mellin transform with properties and to solve the summation series
CO 5	To study and understand about Z- transform with properties and to apply for solving the difference equations

Unit I: Laplace Transforms (Sections-3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8)
Laplace transforms - Definition and Examples, Basic Properties of Laplace Transforms, The Convolution Theorem and Properties of Convolution, Differentiation, and Integration of Laplace Transforms. The Inverse Laplace Transform and Examples, Tauberian Theorems and Watson's Lemma.

Unit II: Applications of Laplace Transforms (Sections-4.1, 4.2, 4.3)
Applications of Laplace Transforms to the Solutions of Ordinary Differential Equations, Partial Differential Equations, Initial and Boundary Value Problems.

Unit III: Hankel Transforms (Sections-7.1, 7.2, 7.3, 7.4)
Introduction, The Hankel Transform and Examples, Operational Properties of the Hankel Transform, Applications of Hankel Transforms to Partial Differential Equations.

Unit IV: Mellin Transforms (Sections- 8.1, 8.2, 8.3, 8.4, 8.6)
Introduction, Definition of the Mellin Transform and Examples, Basic Operational Properties of Mellin Transforms, Applications of Mellin Transforms, Application of Mellin Transforms to Summation of Series.

Unit V: Z Transforms (Sections-12.1, 12.2, 12.3, 12.4, 12.5, 12.6)
Introduction, Dynamic Linear Systems and Impulse Response, Definition of the Z Transform and Examples, Basic Operational Properties of Z Transforms, The Inverse Z Transform and Examples, Applications of Z Transforms to Finite Difference Equations.

Text Book

1. Lokenath Debnath and Dambaru Bhatta, Integral Transforms and Their Applications, Third Edition, CRC Press, Taylor and Francis Group, A Chapman and Hall Book, 2015.

Reference Books:

1. Ian N. Snedden, The Use of Integral Transforms, McGraw Hill, 1972
2. B. Davies, Integral Transforms and Their Applications, Springer, Texts in Applied Mathematics 41, Third Edition,2009.
3. Alexander D. Poularikas, Transforms and Applications Handbook, Third Edition, CRC Press, Taylor and Francis Group, 2010.

Minor:12-19 MATH-535 Wavelet Theory and Applications

(4 Credits)

Course Objectives:

1. To introduce the idea of Fourier series, Fourier transform and Wavelet theory.
2. To study the notion of MRA and some applications in real life applications

	Course Outcome
CO 1	Understand the concept of orthogonal and orthonormal bases in function spaces
CO 2	Learn Fourier transform and wavelet transform.
CO 3	Learn applications of wavelets to the real-world problems

Unit-I: Fourier Series and Fourier Transforms

Fourier cosine and sine series, Fourier series, Differentiation and integration of Fourier series, Absolute and uniform convergence of Fourier series, The complex form of Fourier series. Fourier and inverse Fourier transforms, Fourier sine and cosine transforms, Inverse Fourier sine and cosine transforms, Linearity property, Change of scale property, Shifting property, Modulation theorem, Convolution. [Ruch & Patrick: 2.1,2.2, 2.3, 2.4]

Unit–II: Fourier Transforms and Wavelets

Discrete Fourier transform of a digital signal, Inverse discrete Fourier transform, Window Fourier transform, Short time Fourier transform, Admissibility condition for a wavelet, Wavelet series, Classes of wavelets: Haar, Morlet, Maxican hat, Meyer and Daubechies wavelets; Wavelets with compact support. [Chui: 3.1, 3.2, 3.3, 3.4, 3.6]

Unit-III: Haar Scaling Function and Wavelet, Time-Frequency Analysis

Orthogonal functions, Orthonormal functions, Function spaces, Orthogonal basis functions, Haar scaling function, Haar spaces: Haar space V_0, general Haar space V_j; Haar wavelet, Haar wavelet spaces: Haar wavelet space W_0, general Haar wavelet space W_j; Decomposition and reconstruction, Time-frequency analysis, Orthogonal and orthonormal bases. [Ruch & Patrick: 3.1,3.2, 3.3, 3.4, 3.5]

Unit–IV: Discrete Wavelet Transforms

Stationary and non-stationary signals, Haar transform, 1-level Haar transform, Multi-level Haar transform, Conservation and compaction of energy, Multiresolution analysis, Decomposition and reconstruction of signals using discrete wavelet transform (DWT). [Primer: Ch2: 2.1, 2.2, 2.3, 2.4

Unit–V: Applications

Multiresolution analysis, Applications in signal compression, Analysis and classification of signals using DWT, Signal de-noising: Image and ECG signals. [Ruch & Patrick: 5.1, 4.1, 4.2, 4.6, 4.8, 4.9]

Text Books:

1. Charles K. Chui (1992). *An Introduction to Wavelets*. Academic Press.
2. David K. Ruch & Patrick J. Van Fleet (2009), *Wavelet Theory***:** *An Elementary Approach with Applications*. John Wiley & Sons.
3. James S. Walker (2008). *A Primer on Wavelets and Their Scientific Applications* (2nd edition). Chapman & Hall/CRC, Taylor & Francis.

References:

1. Ingrid Daubechies (1999). *Ten Lectures on Wavelets*. SIAM
2. Michael W. Frazier (1999). *An Introduction to Wavelets Through Linear Algebra*. Springer-Verlag.
3. Stéphane Mallat (2008). *A Wavelet Tour of Signal Processing* (3rd edition). Academic Press.

David F. Walnut (2008), An Introduction to Wavelet Analysis, Springer, 2008.

Minor:12-19 MATH-536 GRAPHS AND ALGEBRAS

(4 Credits)

Unit-I: **Algebraic structures from graphs**: Isomorphism of graphs – Isomorphism as a relation – Automorphism of graphs – Graphs and Groups –The spectrum of a graph – Characteristic polynomial – Adjacency Algebra.

Unit-II: **Graphs defined on groups:** Cayley Graph – Circulant graph – Power graph – Commuting graph, commuting graph – Non-generating graph – Nilpotence graph – Solvability graph – Engel graph – Aut(G)-invariant graph.

Unit-III: **Graphs defined on rings**: Zero-divisor Graph of a ring-Introduction – Basic Properties of zero-divisor Graphs – Total graph of a ring- Introduction – Basic properties of total graphs.

Unit-IV: **Properties of Graphs defined on rings**: Girth of zero-divisor graph of a commutative ring – Diameter of zero-divisor graph of a commutative ring – Girth of total Graph of a commutative ring – Diameter of total graph of a commutative ring.

Unit-V: **More graphs on rings**: Cayley graphs – Co-maximal graphs – Unit graphs – Cozero-divisor graphs – Jacobson graphs – Intersection graphs – Annihilator graphs.

Text Book:-

1. Gary Chartrand, Ping Zhang, Introduction to Graph Theory, Tata McGraw-Hill, 2006. (Unit-I)
2. Norman Biggs, Algbraic Graph Theory, Second Edition, Cambridge University Press, 1993. (Unit-I)
3. Peter J. Cameron, Graphs defined on groups, International Journal of Group Theory, 11(2), 2022, 53-107. (Unit-II)
4. David F. Anderson, T. Asir, Ayman Badawi, T. Tamizh Chelvam, Graphs from rings, Springer Switzerland, 2021. (Unit-III,IV,V)

Reference Books:-

1. Chris Godsil and Gordon Royle, Algebraic Graph Theory, Springer 2009.
2. R. Balakrishnan and K. Ranganathan, A Textbook of Graph Theory (Universitext), Second Edition, Springer New York, 2012.

Minor: 12-19 MATH-537: Probability and Statistics (4 Credits)

Objectives:

To study the basics of Probability density function, Special distributions, Distributions of functions of random variables, Sampling theory and Statistical inference.

Unit I: The probability set function – Random variables – Probability density function – Distribution function – Mathematical expectation – Special mathematical expectations – Chebyshev's Inequality – Conditional probability – Marginal and conditional distributions – Stochastic independence. *[Chapters 1 and 2 (except 1.1and 1.2) of the text book]*

Unit II: Some special distributions: The Binomial and related distributions – The Poisson distribution – The Gamma and Chi-Square Distributions – The Normal distribution- The Bivariate normal distribution. *[Chapter -3 of the text book]*

Unit III: Distributions of functions of random variables - Sampling theory – Transformations of variables of the discrete type – Transformations of variables of the continuous type – The b, t and F distributions- Distributions of order statistics- The moment generating function technique. *[Chapter 4 [sections 4.1 to 4.7] of the text book.]*

Unit IV: The distributions of $\bar{X}$ and nS^2/σ^2 - Expectations of functions of random variables – Limiting distributions: Limiting moment generating functions – The Central limit theorem. *[Chapter-4 [sections 4.8 and 4.9] and Chapter-5 of the text book.]*

Unit V: Introduction to statistical inference: Point Estimation – Confidence intervals for means – Confidence intervals for differences of means - Confidence intervals for variances. *[Chapter-6 of the text book]*

Text Book:

Robert V. Hogg and Allen T. Craig , *Introduction to Mathematical Statistics* (Fifth Edition) Pearson Education, 2005.

Reference Books:

1. Paul L.Meyar, *Introductory to Probability and Statistical Applications*, Oxford&IBH Publishers Co. Pvt .Ltd, 1969.
2. Arnold Naiman, Gene Zirkel and Robert Rosenfield, *Understanding Statistics*, McGraw- Hill, 1986.
3. William Feller, *An Introduction to Probability Theory and its Applications, Vol.I*, John Wiley, Third Edition, 2008.
4. A.Mood, F.Graybill, and D.Boes, *Introduction to the Theory of Statistics*, Tata McGraw Hill (Third Edition) 2008.

Minor:12-19 MATH 538: ALGEBRAIC NUMBER THEORY (4 CREDITS)

Course Objectives:

1. To study about the application of unique factorization in integers
2. To find the primes of Gaussian integers

	Course Outcome
CO 1	Construction of transcendental numbers using Liouville's theorem
CO 2	To study about the integral basis and discriminant of algebraic number fields
CO 3	To study about Dedekind domains.

Unit I: Elementary Number Theory (Sections 1.1 and 1.2)

Integers – Greatest common divisor – Infinitude of primes – Unique factorization in Z – Fermat's little theorem – Euler's Φ function and Euler's theorem – Multiplicative property of Φ function – Applications of unique factorization – The equation $x^2 + y^2 = z^2$ – The equation $x^4 + y^4 = z^2$ – The equation $x^4 – y^4 = z^2$ – Fermat numbers and their properties.

Unit II: Euclidean Rings(Sections 2.1, 2.2 and 2.3)

Preliminaries: Units, Associates, Irreducible elements, Norm map, Unique factorization domain, Principal ideal domain, Euclidean domain – Gauss' lemma – Gaussian integers – Units and primes in the ring of Gaussian integers – Eisenstein integers – Units in the ring of Eisenstein integers – Factorization of 3 – Order of $Z[\rho] / (\lambda)$.

Unit III: Algebraic Numbers and Integers (Sections 3.1, 3.2 and 3.3)

Basic concepts – Algebraic number – Algebraic integer – Minimal polynomial Count ability of algebraic numbers – Liouville's theorem for R – Algebraic number fields – Theorem of the primitive element –Liouville's theorem for C – Characterization of algebraic integers.

Unit IV: Integral Bases (Sections 4.1, 4.2 and 4.3)

The norm and the trace – Integral basis for an algebraic number field – Algebraic integers of $Q(\sqrt{-5})$ – Existence of an integral basis – Discriminant of an algebraic number field – Index – Determination of an integral basis for the ring of integers of a quadratic number field.

Unit V: Dedekind Domains (Sections 5.1 and 5.2)

Integral closure – Integrally closed ring – Noetherian ring – Dedekind domain – Characterizing Dedekind domains.

Text Book

J. E. Smonde and M. RamMurty, Problems in Algebraic Number Theory,
Graduate Texts in Mathematics, Volume 190, Springer Verlag, New York,1999.

Reference Books:

1. Pierre Samuel and Allan J Silberger, Algebraic Theory of Numbers, Dover Pub. Inc, 2008.

Minor:12-19 MATH 539: ADVANCED TOPICS IN TOPOLOGY AND ANALYSIS
(4 CREDITS)

Course Objectives:

1. To study metrization theorem.
2. To study about the dual of $L^p[a,b]$.

	Course Outcome
CO 1	To learn the quotient topology and path connectedness
CO 2	To learn Urysohn Metrization theorem and compactification
CO 3	To learn about the completeness of $L^p[a,b]$

Unit I: (Sections 22,25, relevant parts from section 24 of [1])

Quotient topology and quotient maps - Examples of quotient spaces - Path connectedness - Standard results - Example of a connected but not path connected space- Locally connected spaces.

Unit-II: (Sections29, 34,38, 43,44 of [1])

The Uryshon's metrization theorem – Locally compact spaces-One point compactification - Stone- Cech compactification – The uniform metrric on Y^J and the Space filling curve.

Unit-III: (Sections 39, 40,41 of [1])

Local finiteness- Countably locally finite refinement of open coverings of metric spaces – Paracompactness - Standard results - Metric spaces are paracompact.

Unit-IV: (Chapter:7 of [2])

L^p- spaces – Completeness - Dual of $L^p[a,b]$for $1 \leq p < \infty$.

Unit-V: (Sections 8.1, 8.2 and 8.3 from Chapter:8 of [2])

Weak sequential convergence of $L^p[a,b]$ – the Riemann Lebesgue lemma – the Radon Riesz theorem - weak sequential compactness of $L^p[a,b]$.

Text Books:

1. James R. Munkres, Topology by James R. Munkres, Pearson, 2nd edition, 2000.
2. H.L.Royden, and P.M. Fitzpatrick, Real Analysis, (Fourth Edition) PHI Learning Private Limited, 2013.

Reference Books:

1. James Dugundji, General Topology, Allyn and Bacon, Inc.(1966).
2. Inder K. Rana, *An Introduction to Measure Theory and Integration, (2e)*, Narosa (2007).
3. B.V. Limaye, Functional Analysis, Wiley Eastern, New Delhi, 1981.

Minor:12-19 MATH 540: ADVANCED TOPOLOGY

(4 CREDITS)

Course Objectives:

1. To study about the notions of local connectedness, local compactness and one point compactification
2. We study about nets, filters and quotient topology

	Course Outcome
CO 1	We study about Stone -Cech Compactification and some Metrization theorems
CO 2	To learn about space filling curve and the imbedding theorem for compact metrizable spaces
CO 3	To study about fundamental groups and covering spaces

Unit I: (Sections- 25 and 29 of [1])

Connected components- Local connectedness - Locally path connected spaces- Local compactness, One point Compactification, Uryshon Metrization Theorem.

Unit II:(Chapter-10 of [2] and Sections- 22 and 36 of [1])

Nets and Filters- Quotient topology- Introduction to topological groups.

Unit III:(Sections-38, 39, 40, 41 and 42 of [1])

The Stone -Cech Compactification- Locally finite spaces- Nagata- Smirnov Metrization theorem- Paracompactness- Smirnov Metrization theorem.

Unit IV: (Sections-44 48 and 49 of [1])

The Peano space-filling curve – Barie Spaces – Nowhere differentiable functions.

Unit V: (Sections 48, 49, of [1])

Homotopy of paths- The fundamental group- Covering spaces- The fundamental group of the circle.

Text Books:

1. James R. Munkres, Topology, Second edition, Pearson Education Inc.,(2002).
2. K.D.Joshi, Introduction to General Topology, First edition (revised), New Age International Publishers, 2004.

Reference Books:

1. Stephen Willard, General Topology, Dover, 2004.

Minor:12-19 MATH 541: COMMUTATIVE ALGEBRA (4 Credits)

Objectives:
To study the basics of Prime ideals, Operation on sub-modules, Tensor product and Noetherian rings.

Unit-I
Prime ideals- Maximal ideas- Nil radical- Jacobson radical- Operation on ideals- Extension and contraction.

Unit-II
Operation on sub-modules- Direct sum and product- Finitely generated modules- Exact sequences- Tensor product- Restriction and extension of Scalars.

Unit-III
Rings and Modules of Faction and Primary decomposition Local properties extended and contracted Primary decomposition.

Unit-IV
Integral dependence and chain conditions.

Unit -V
Noetherian rings and Artinian rings

Text Book
M. K. Atiyah and I. G. Macdonald, Introduction to Commutative Algebra, Addison-Weseley, 1994.

Reference Books

1. H. Matsumura, Commutative Ring Theory, Cambridge University Press,1989.
2. I. Kaplansky, Commuatavie Rings, University of London press,1966.
3. O. Zariski and P. Samuel, Commutative Algebra, Springer 1976.

Minor:12-19 MATH-542 DISCRETE DYNAMICAL SYSTEMS (4 Credits)

Objectives:
To study the basics of Orbits, Symbolic dynamics, Topological Conjugacy and The dynamics of Complex functions.

Unit-I
Orbits - Phase portraits- Periodic points and stable sets. Sarkovskii's theorem

Unit-II
Attracting and repelling periodic points- Differentiability and its implications – Parametrized family of functions and bifurcations- The logistic map.

Unit-III
Symbolic dynamics - Devaney's definition of Chaos - Topological Conjugacy.

Unit-IV
Newton's method-Numerical solutions of differential equations.

Unit-V
The dynamics of Complex functions- The quadratic family and the Mandelbrot set.

Text Book
Richard A. Holmgren, A First Course in Discrete Dynamical Systems, Springer Verlag (1994).

Unit-I [Chapters: 1, 2, 4 and 5], Unit-II [Chapters: 6, 7 and 8], Unit-III [Chapters: 9, 10 and 11], Unit-IV [Chapters: 12 and 13], Unit-V [Chapters 14 and 15].

Reference Books:

1. Robert L.Devaney, A First Course in Chaotic Dynamical Systems, Addison-Wesley Publishing Company, Inc. 1992.

Minor: 12-19 MATH-543 ADVANCED SEPCIAL FUNCTIONS

(4 Credits)

Course Objectives:

1. To learn and understand about generalized hypergeometric function and their properties
2. To learn and understand about Laguree and Hermite polynomials including properties

1.

	Course Outcome
CO 1	To study and discuss about GHF and various properties and summation formulas
CO 2	To study about Laguree Polynomials and Hermite Polynomials their properties
CO 3	To study about Appell hypergoemetric function of two variables with properties

Unit I: (Chapter 4)

Basics and Introduction to Gauss's hypergeometric and Confluent hypergeometric functions, integral representations, differentiation formulas, transformation formulas, contiguous function relations, summations formulas. **(12 hours)**

Unit- II (Chapter 5)

Generalized Hypergeometric Functions: The function pFq, The contiguous function relations, A simple integral, The pFq with unit argument, Saalschutz' theorem, Whipple's, Dixon's, **(12 hours)**

Unit- III (Chapter 11)

Hermite Polynomials- Definition, recurrence relation, Rodrigues formula, orthogonality property, generating relations and general properties. **(12 hours)**

Unit IV (Chapter 12)

Laguree Polynomials-. Definition, recurrence relation, Rodrigues formula, orthogonality property, generating relations and general properties **(12 hours)**

Unit V: (Chapter 9 of Ref 2)

Appell's hypergoemtric function of two variables, Transformation formulas, integral representation of Euler and Laplace type **(12 hours)**

Text Books :

1. E. D. Rainville, Special functions, Macmillan, New York, 1960. (Chapter 5)
2. W.N. Bailey, Generalized Hypergeometric Series, Cambridge University Press, Cambridge, (1935)

Reference Books:

1. W.N. Bailey, Generalized Hypergeometric Series, Cambridge University Press, Cambridge, (1935)
2..L.J. Sater, Generalized Hypergeometric function, Cambridge University Press, London and New York, 1966

Minor: 12-19 MATH-544 ADVANCED FUNCTIONAL ANALYSIS

(4 CREDIT)

Objectives:

To study the basics of Canonical isometry, Compact operators, Eigen values and the eigen spectrum of a linear operator, The adjoint of an operator and Spectral results for Hilbert's space operators.

Unit-I

Duals of $\mathcal{C}[a,b]$ and $L_p[a,b]$– Separability – The Canonical isometry – The transpose of a bounded linear Map – Reflexivity – Weak convergence – Schur's Lemma – EberleinShmulyan Theorem – Best approximation in reflexive spaces.

Unit-II

Compact operators – Examples – Properties – The completeness of the space of compact operators – Compactness of the transpose.

Unit-III

Eigen values and the eigen spectrum of a linear operator – examples – spectrum and resolvent set – Spectral radius – Spectral Mapping Theorem – Resolvent Identity – The specrtral radius formula – The RieszSchauder Theory.

Unit-IV

The adjoint of an operator – Existence – Compactness of the adjoint operator – Sesquilinearfunctionals – Closed range Theorem.

Unit-V

Self-adjoint, normal, unitary operators – Numerical range and numerical radius – Spectral results for Hilbert's space operators – Properties of the Spectrum.

Text Book:

1. M.Thamban Nair, *Functional Analysis: A First Course*, Prentice Hall of India, 2002.

Unit-I Sections: 8.1.3, 8.1.4, 8.2.1, 8.2.2,8.2.3
Unit-II Sections: 9.1, 9.2, 9.3
Unit-III Sections: 10.1, 10.2, 10.2.1, 10.2.2, 10.2.3, 10.4
Unit-IV Sections: 11.1, 11.1.1, 11.1.2
Unit-V Sections: 11.2, 12.1, 12.1.1, 12.2

Reference Books:

1. Joseph Muscat, *Functional Analysis*, Springer (2008).
2. BalmohanV.Limaye, *Functional Analysis*,3e, New Age International Publishers (2014).
1. Erwin Kreyszig, *Introductory Functional Analysis with Applications*, John Wiley (2007).
2. Martin Schecter, *Principles of Functional Analysis*, American Mathematical Society (2009)
3. BelaBollobas, *Linear Analysis: An Introductory Course*,2e, Cambridge Univ. Press (1999).
4. Bryan P. Rynne and Martin.AYoungson, *Linear Functional Analysis*, Springer (2008).

Minor: 12-19 MATH-545 NON-COMMUTATIVE RINGS AND REPRESENTATIONS (4 Credits)

Objectives:

To study the basics of Modules, Semi simple rings, Structure theory of ring and substantial study of Representations.

Unit-I Modules

Modules - Artinian and Notherian modules - Tensor products - Restricted and induced modules. - Indecomposable modules – Completely reducible module - Schur Lemma.

Unit-II Radical

Semi simple rings - The radical of a rings – The properties of Jacobson radical

Unit-III Group algebras - The Jacabson radical of Group Algebra – Maschke's Theorem.

Unit-IV Structure theory

Structure theory of ring - Density theorem - Widderburn-Artin theorem for semi simple rings.

Unit-V Representations

Representations - linear representation - Matrix representation - Equivalent representation - Invariant subspaces - Irreducible representations - Direct sum of representations - Induced representation – restricted representation - Tensor product of representations - Inner products of representation.

Text Book

1. I. N Herstein, Non-Commutative Rings, The Mathematical Association of America, 5th Edition, 2005 (Chapter 1: Units I-III, Chapter 2: Unit IV and Chapter 5: Unit V)

Reference Books:

1. William Fulton and Joe Harris, Representation Theory - A First Course, Springer International Edition, Springer-Verlag, New York, 2004.
2. Jacobson, Basic Algebra II, Hindustan Publishing Corporation (India), 1983.
3. Charles W. Curtis and Irving Reiner, Representation Theory of Finite Groups and Associative Algebras, Inter Science Publishers, 1962.

Minor: 12-19 MATH-546: ALGEBRAIC GRAPH THEORY (4 Credits)

Objectives:
To study the objectives of Linear Algebra in Graph Theory, Spanning Trees and Associated Structures, The Multiplicative Expansion and Chromatic Polynomial.

Unit -I: Linear Algebra in Graph Theory – The Spectrum of a Graph – Characteristic polynomial – Adjacency Algebra - Reduction Formula for χ – Regular Graphs and Line Graphs – Circulant Graph – Spectrum of the Strongly Regular Graph – Cycles and Cuts – The Incidence Matrix – The Laplacian Spectrum.

Unit -II: Spanning Trees and Associated Structures – Kirchhoff's Law – Thomson's Principle – The Tree-Number – A Bound for the Tree Number of Regular Graphs – Determinant Expansions – Elementary Graphs.

Unit -III: Vertex-Partition and the Spectrum – Color Partition – Wilf's Theorem on the Chromatic Number of a Graph – Coloring Problems – The Chromatic Polynomial – Recursive Relation for the Chromatic Polynomial – Quasi-Separable Graphs – Subgraph Expansions – The Rank Polynomial.

Unit -IV: The Multiplicative Expansion – Whitney's Theorem on Counting Subgraphs – The Induced Subgraph Expansion – Baker's Theorem.

Unit -V: The Tutte Polynomial – The λ-operator – The Deletion-Contraction Property – Chromatic Polynomial and Spanning Trees – The Chromatic Invariant.

Text Book:-

1. Norman Biggs, Algbraic Graph Theory, Second Edition, Cambridge University Press, 1993.

Reference Books:-

1. Chris Godsil and Gordon Royle, Algebraic Graph Theory, Springer 2009.
2. R. Balakrishnan and K. Ranganathan, A Textbook of Graph Theory (Universitext), Second Edition, Springer New York 2012.

Minor: 12-19 **MATH 547: FIXED POINT THEORY (4 CREDITS)**

Course Objectives:

1. We study about metric convexity and some of its consequences
2. We learn about set valued contractions and hyper convexity

	Course Outcome
CO 1	To study about normal structures in metric spaces
CO 2	We prove some of the important theorems like Brouwer's Theorem and Schauder's Theorem
CO 3	To study about non-expansive maps and the structure of fixed points sets

Unit I (I Sections: 2.5,3.1 to 3.4**):** Metric convexity and convexity structure-Bananch contraction principle and its extensions-The Casristi-Ekelandprincipleand its equivalent.

Unit II (Sections 3.5,3.6, 4.1 to 4.5**):** Set valued contractions-Generalised contractions-Hyperconvexity-Propertiesof hyper convex spaces.

Unit III (Sections: 4.6, 4.7, 5.1 to 5.4**):** Approximate fixed points-Isbell's hyper convexhull-Normal structures in metric spaces-Structure of fixed point sets-Uniform normal structures- Uniform relative normal structure-

Unit IV (Sections: 5.5 to 5.7 , 7.1 to 7.6**):** Quasi normal structure-stability and normal structure- Ultrametric spaces- Continuous mappings in Banach spaces-Brouwer's Theorem-Schauder's Theorem- Stability of Schauder's theorem—Continuous mappings in hyper convex spaces.

Unit V (Sections8.1 to 8.8**):** Basic theorems for nonexpansive maps-Stability results in arbitrary spaces- The Gobel_Karlovitz Lemma-Orthogonol Convexity-Structure of fixed point set-Asymptotically regular mapppings.

Text Book: M. A. Khamsuans W.A. Kirk, An Introduction to Metric Spaces and Fixed Point Theory, John Wiley & Sons, 2001.

Reference Books:

1. Kazimierz Goebel and W. A. Kirk, *Topics in Metric Fixed Point Theory*, Cambridge University Press, 1990.
2. M.C.Joshi and R.K.Bose, *Some topics in Nonlinear Functional Analysis*, John Wiley &sons 1986.

Minor: 12-19 **MATH 548 GRAPH COLORING (4 CREDITS)**

Course Objectives:

1. To study perfect graphs, color critical graphs and greedy coloring of graphs
2. To introduce the four-color problem and some new coloring parameters like list coloring and precoloring extension.

	Course Outcome
CO 1	To study the edge coloring, Tait coloring and total coloring of graphs and some of their properties
CO 2	We introduce the concept of graph homomorphism, Grundy coloring and achromatic coloring of graphs and establish some of the basic properties
CO 3	We introduce T-coloring, L(2,1)-coloring, Radio coloring and Hamiltonian coloring of graphs

Unit I: Vertex Colorings and Bounds of the Chromatic number (Sec: 6.1, 6.3, 7.1-7.2) : The Chromatic Number of a Graph– Perfect Graphs – Color-Critical Graphs – Upper Bounds and Greedy Colorings –The Chromatic Number of Cartesian Products.

Unit II: Coloring Graphs on Surfaces & Restricted Vertex Colorings (7.4, 8.1- 8.3**):** The Four Color Problem – The Conjectures of Hajós and Hadwiger – Chromatic Polynomials –Uniquely Colorable Graphs – List Colorings – Precoloring Extensions of Graphs.

Unit III: Edge Colorings of Graphs (9.1-9.3, 10.1-10.4, 10.6 **):** The Chromatic Index and Vizing's Theorem – Class One and Two Graphs – Tait Colorings – Nowhere-Zero Flows – Total Colorings of Graphs.

Unit IV: Complete Colorings (12.1-12.3**):** The Achromatic Number of a Graph – Graph Homomorphisms – The Grundy Number of a graph.

Unit V: Colorings, Distance and Domination (14.1-14.4**):** T-Colorings – L(2,1)-Colorings – Radio Colorings – Hamiltonian Colorings.

Text Book: Gary Chartrand, Ping Zhang, Chromatic Graph Theory, Chapman & Hall/CRC press, 2009.

Reference books:

1. Douglas B. West, Introduction to Graph Theory, Second Edition, PHI Learning Private Ltd, New Delhi-2011.
2. G. Chartrand, Linda Lesniak and Ping Zhang, Graphs and Digraphs, Fifth Edition, CRC press 2011.
3. Michael Molloy and Bruce Reed, Graph Colouring and the Probabilistic Method, Springer 2002.
4. Tommy R. Jensen and Bjarne Toft, Graph Coloring Problems, John Wiley and Sons, 1995.

MATH-901 Research Methodology (4 Credits)

(Pre-Ph.D Course for all the Ph.D. Students of Department of Mathematics)

UNIT -1: Introduction: Meaning of Research - Objectives of Research - Motivation in Research- Research Methods versus Methodology -Research and Scientific Method - Criteria of Good Research - Defining the Research Problem - Selecting the Problem- Necessity of Defining the Problem - Technique Involved in Defining a Problem.

UNIT -2: Research Design: Meaning of Research Design - Need for Research Design - Research Methodology Features of a Good Design -Important Concepts Relating to Research Design - Different Research Designs - Basic Principles of Experimental Designs.

UNIT -3: Data Collection: Collection of Primary Data - Observation Method - Interview Method - Collection of Data through Questionnaires - Collection of Data through Schedules -Difference between Questionnaires and Schedules - Some Other Methods of Data Collection Guidelines for Constructing Questionnaire/Schedule.

UNIT -4:Computer Applications : Features for data analysis, generating charts/graphs & other features-Presentation tool: Introduction to presentation tool, features & functions, creating presentations

Unit – 5 : Report Writing: Significance of Report Writing - Different Steps in Writing Report - Layout of the Research Report - Types of Reports - Oral Presentation - Mechanics of Writing a Research Report - Precautions for Writing Research Reports.

Use of Latex (and/or) MS Office for generating, storing and interpreting data
Report Writing using either Latex or MS Office

Text Book:

Kothari C.R, Research Methodoloy – Methods and Techniques , New Age International, New Delhi.

Unit –1: Chapters 1 & 2, Unit –2 : Chapter 3, Unit – 3 : Chapter 6 , Unit – 4 & 5 :Chapter 14

Reference Book:

Ranjit Kumar, Research Methodology – A step by step Guide for Beginners,
Pearson Education, Delhi.
Chawla D and Sondhi N,Research Methodology Concepts and cases,Vikas Publishing House Pvt. Ltd., New Delhi.

MULTIDISPLINARY COURSE

MATH 100: BASIC MATHEMATICS
(3 CREDITS)

Course Object:

To learn the basic of Mathematical logics, combinatorics and the algebra of matrices.

CO 3	To introduce the idea of matrices and learn above
CO 4	To introduce the basic concept of permutation-Combinations
CO 5	The learn logics, truth table and basic set theory.

Unit I:
Linear System – Matrices – dot Product – Matrix multiplication – properties of Matrix operations – Matrix transformation.

Unit II:
Solution of linear system of equations – row echelon form – reduced row echelon form – Polynomial interpolation – inverse of a matrix – linear systems.

Unit III:
Logic – truth table – algebra of propositions- logical arguments – sets- operations on sets.

Unit IV:
Principle of inclusion – exclusion – the addition and multiplication rules – pigeonhole principles.

Unit V:
Permutations – Combinations – Elementary Probability.

Text Book:

1. Bernard Kolman, Dred. R. Hill, Introductory Linear Algebra, 8th edition – peasson, India 2011.
2. Edgar G. Goodaire, Michael. M. Parmenter, Discrete Mathematics with Graph Theory, 3e PHI, India, 2011.

SKILL ENHANCMENT COURSE

SEC-1 MATH 111 LATEX FOR MATHEMATICS (3 CREDITS)

Course Objectives:

1. To learn about the Latex software
2. To prepare a Latex document, to make scientific article and project report.

	Course Outcome
CO 1	**To enable to prepare documents in Latex using different kind of fonts in different sizes**
CO 2	**To learn how to prepare any kind of Mathematical equations.**
CO 3	**To know how to construct various kind of tables, lists in Latex.**

Unit I:

Installation of the software LaTeX Understanding Latex compilation

Unit II:

Creating different kind of documents - Creating Title, sections, subsections, Using various types and sizes of fonts.

Unit III:

Creating Tables, enumeration list, itemized list.

Unit IV:

Constructing Mathematical equations,

Unit V:

Including pictures in a document- Inserting foot notes and references

Reference books

1. L. Lamport: A Document Preparation System, User's Guide and Reference Manual, Addison - Wesley, New York, second edition, 1994.
2. M.R.C. van Dongen: LATEX and Friends, Springer-Verlag Berlin Heidelberg 2012.
3. Stefan Kottwitz: LATEX Cookbook, Packt Publishing 2015.

David F. Griffths and Desmond J. Higham: Learning LATEX (second edition), Siam 2016.

SEC-2 **MATH 211 SCILAB FOR MATHEMATICS (3 CREDITS)**

Course Objectives:

1.To learn about the SCILAB free and Open source software

2.To familiarize with commands, operations and how to evaluate and compute mathematical equations using SCILAB.

3. To learn to plot functions using SCILAB

	Course Outcome
CO 1	**To enable learners to Install the FOSS SCILAB into their Desktops/Laptops**
CO 2	**To learn to familiarize with various SCILAB Commands to perform calculations**
CO 3	**To evaluate, compute various Mathematical equations and Plotting functions**

Unit-I: SCILAB Basics: Overview of SCILAB – Get started – Basic elements of the language – Matrices

Unit-II: SCILAB Programming, Looping and Branching – Functions – Plotting

Unit-III: SCILAB for Differential Calculus

Unit-IV: Scilab for Integration

Unit-V: Scilab for Linear Algebra

Text Books:

1. Introduction to SCILAB – Michael Baudin From SCILAB Consortium, 2010
2. SCILAB Online Materials:
3.https://help.scilab.org/docs/5.5.2/en_US/section_33491857221a48388b878311e9f4b67e.html

Reference Books:

1. https://www.scilab.org/tutorials
2. SCILAB help documentation – Statistics
3.https://www.scilab.org/sites/default/files/Basic%20Statistics%20and%20Probability%20with%20SCILAB%20-%20Gilberto%20E.%20Urroz%20-%202001.pdf

SEC-3 **MATH 121** **Mathematical Methods with MATLAB (3 CREDITS)**

	Course Outcome	**Level**
CO 1	To know basics of MATLAB.	
CO 2	To understand different data types and their uses.	
CO 3	To understand script files, function files and language specific feature.	
CO 4	To know application of MATLAB in some branches of Mathematical Sciences.	
CO 5	To visualize some graphics and toolboxes.	

Unit-I: Basics of MATLAB (Sec: 1.1, 1.6 (1.6.1, 1.6.3-1.6.6), 2.2-2.6, 2.8, 2.9)

Programming, Basics of MATLAB, Input-output, File types, General commands, Creating and working with arrays of numbers, Printing simple plots, Creating; saving and executing a script file, Creating and executing a function file, Arrays and matrices, Symbolic computation Importing and exporting data.

Unit–II: Interactive Computation (3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 3.7, 3.8)

Matrices and vectors, Matrix and array operations, Character strings, A special note on array operations, Command-Line functions, Built-in functions, Saving and loading data, Plotting simple graphs.

Unit-III: Scripts and Functions (4.1, 4.2, 4.3, 4.4, 4.5)

Script files, Function files, Language-specific features, Advanced data objects, Publishing reports.

Unit–IV: Applications in Mathematical Sciences (5.1, 5.2, 5.3, 5.4, 5.5, 5.6, 5.7)

Linear Algebra, Curve fitting and interpolation, Data analysis and statistics, Numerical integration, Ordinary differential equations, Nonlinear algebraic equations, Partial differential equations.

Unit–V: Graphics and Toolbox (6.1, 6.2, 6.3, 6.4, 6.6, 6.7, 8.1, 8.2, 8.5)

Basic 2-D plots, Using subplot for multiple graphs, 3-D plots, Handle graphics, Saving and printing graphs, Animation, The symbolic math toolbox, Numeric versus symbolic computation, Using MuPAD notebook.

Text Book:

1. Rudra Pratap (2010), Getting Started with MATLAB, Oxford University Press.

References:

1. Gilat A (2012), Matlab An Introduction with Applications (4th Edition), John Wiley.
2. R K Bansal, A K Goyal, M K Sharma, MATLAB and its Applications in Engineering, 2nd Edition, Pearson.
3. S S Alam S N Alam (2019), Understanding MATLAB A Textbook for Beginners, Wiley India.

MINOR COURSES OFFERED FOR MATHEMATICS STUDENTS

MATH 200: NUMERICAL METHODS (4 Credits)

Course Objectives:

1. To understand different types of errors.
2. To obtain numerical solutions of algebraic and transcendental equations.

	Course Outcome
CO 1	To learn about various interpolating and extrapolating methods.
CO 2	To perform differentiation and integration using numerical methods.
CO 3	To apply various numerical methods in solving systems of equations.

Unit I (Sections: 1.2, 1.3, 2.1,2.2,2.3**):** Roundoff errors and computer arithmetic-The rate of convergence of a sequence of real numbers- Bisection method-Fixed point iteration method-Newton's Method-Secant Method-Method of False position.

Unit II (Sections: 2.4,2.5,3.1,3.2,3.4**) :** Error Analysis for iterative methods-Accelerating convergence-Muller's Method-Lagrange's interpolation polynomial-Divided Differences-Newton's divided difference formula-Cubic Spline interpolation.

Unit III (Sections: 4.1, 4.3,4.4**):** Numerical differentiation-Numerical Integration-Trapezoidal rule – Simpson's rules-Composite Numerical integration

Unit IV (Sections: 6.1,6.2,6.4,6.5,6.6**):** System of linear equations-Gauss elimination method-Gauss Jordan Method-Pivoting strategies-LU factorization- Crout's Method.

Unit V (Sections: 7.1,7.2,9.2**):** Norms of vectors and matrices-Jacobi iterative method-Gauss Seidel iterative method-The power method.

Text Book: Richard L. Burden and J. Douglas Faires, Numerical Analysis, (7^{th} edition) CENGAGE Learning 2001.

Reference Books

1. Brian Bradle, A Friendly Introduction to Numerical Analysis , Pearson India, 2007
2. M.K.Jain, S.R.K.Iyengar and R.K Jain, Numerical Methods for Scientific and Engineering Computation, New Age International Publishers 2012.
3. Sauel D Conte and Carl de Boor, Elementary Numerical Analysis(3e), Tata Mcgraw Hill.

MATH 201 : PYTHON (4 Credits)

Course Objectives

1. To be able to model and solve mathematical problems using Python.
2. To explore the practical benefits of open-source resources in numerical and symbolic mathematical software systems.

Course Outcomes

CO 1	To apply mathematical problem-solving involving both numerical and symbolic computation.
CO 2	To create tables and generate a variety of function plots while gaining an understanding of visualizing shapes, geometrical patterns, and fractals.
CO 3	To understand the use of Python in diverse branches of Mathematical Sciences.

Unit I: Drawing Shapes, Graphing and Visualization : Drawing diverse shapes using code and Turtle; Using matplotlib and NumPy for data organization, Structuring and plotting lines, bars, markers, contours and fields, managing subplots and axes; Pyplot and subplots, Animations of decay, Bayes update, Random walk.

Unit II: Numerical Solutions of Mathematical Problems: NumPy for scalars and linear algebra on n-dimensional arrays; Computing eigenspace, Solving dynamical systems on coupled ordinary differential equations, Functional programming fundamentals using NumPy.

Unit III: Symbolic Solutions-I : Symbolic computation and SymPy: Differentiation and integration of functions, Limits, Solution of ordinary differential equations, Computation of eigenvalues, Solution of expressions at multiple points (lambdify), Simplification of expressions.

Unit IV: Symbolic Solutions-II : Factorization, Collecting and canceling terms, Partial fraction decomposition, Trigonometric simplification, Exponential and logarithms, Series expansion and finite differences, Solvers, Recursive equations.

Unit V: Document Generation with Python : Pretty printing using SymPy; Pandas API for IO tools: interfacing Python with text/csv, HTML, LaTeX, XML, MSExcel, OpenDocument, and other such formats; Pylatex and writing document files from Python with auto-computed values, Plots and visualizations.

Text Books

1. Peter Farrell, Math Adventures with Python, No Starch Press, US 2019.
2. Farrell, Peter and et al. The Statistics and Calculus with Python Workshop, 1st edition, Packt Publishing 2020.
3. Amit Saha, Doing Math with Python, No Starch Press, US 2015.

Reference Book

1. Sam Morley, Applying Math with Python, 2nd edition, Packt Publishing 2022.
2. Online resources and documentation on the libraries, viz
https://patrickwalls.github.io/mathematicalpython/
https://matplotlib.org, https://sympy.org,
https://pandas.pydata.org, https://numpy.org, https://pypi.org,

MATH 202 : ELEMENTS OF MECHANICS (4 Credits)

Course Objectives:

1. To Introduce the concepts of space, time and paths; Equations of Motion
2. To make the students understand the moving frames of references, Rotating frames.
3. To enable the students to learn Rigid Body motions.

	Course Outcome
CO 1	Students apply the concepts of motion in one and two dimensions and rigid body motions.
CO 2	Students understand the particles moving in a rotating frame of reference.

Unit I:Newton's laws and Central forces: Introduction, Space, time, and paths, forces, Newton's second law, One-dimensional motions, Particle motion in two and three dimensions, Moving frames of reference Central forces and angular momentum, The scalar equations of motion in place polar coordinates, the equation of path, Condition for stability of circular orbits, General examples.

Unit II:Energy and Rotating frames: The one-dimensional case, the general case, Conservation of energy, Application to central forces, Motion of a particle on a surface under gravity. Two dimensional Rotating Frame, Angular Velocity Vector, Particle moving in a rotating frame of reference, Motion on the surface of the earth.

Unit III:Many-particle systems, Rigid bodies: equations: Motion of centre of mass, Angular momentum and moment of force, Rigid bodies: degrees of freedom, the angular velocity.

Unit IV:Rigid bodies: equations: The equations of motion, Angular momentum and angular velocity, Calculation of the inertia tensor, Application to calculation of angular momentum, Energy.

Unit V:Soluble problems in rigid body motion: Bodies with dynamical symmetry, Bodies with axial symmetry: top, Precession, General rotation of a rigid body fixed at one point, Rolling spheres.

Text Book: Mary Lunn, A First Course in Mechanics, Oxford New York, Tokyo, Oxford University Press 1991.

Reference Books

1. Mechanics -P. Duraipandian S. Chand Limited, 1995
2. Classical Mechanics: Goldstein, Pearson Education India 2002
3. Classical Mechanics: Rana & Joag, Rana, Tata McGraw-Hill Education, 2001

MATH 300: MATHEMATICAL MODELLING (4 Credits)

Course Objectives:

1. To understand different mathematical models
2. To provide students with a solid foundation solving real life problems with mathematical models.

Course Outcomes: After completing this course, students will be able:

CO1	To understand fundamentals of different mathematical models.
CO2	To apply mathematical models in diverse fields of real-life applications
CO3	To know the applications of mathematical models in the fields of academia and industries.

Unit I: History of Mathematical Modeling, Latest development in Mathematical Modeling, Merits and Demerits of Mathematical Modeling, Quantitative and Qualitative approach of modeling, Conceptual and Physical models, stationary and nonstationary models, distributed and lumped models, models in real world problems

Unit II: Introduction to difference equations, Non-linear Difference equations, Steady state solution and linear stability analysis. Discrete dynamical systems: equilibrium and long-term behavior, Linear Models, Growth models, Decay models, Drug Delivery Problem, Linear Prey-Predator models, Volterra's principle, Lanchester combat model.

Unit III: Application of first order differential equations to acceleration-velocity model, Growth and decay model. Introduction to Continuous Models, Drug Distribution in the Body, Interacting population models, Epidemic Models (SI, SIR, SIRS, SIS, SEIR), Steady State solutions, Linearization and Local Stability Analysis, logistic, predator-prey model, Competition models.

Unit IV: Introduction to compartmental models, Lake pollution model (with case study of Lake Burley Griffin), Exponential growth of population, Limited growth of population, Limited growth with harvesting, Battle model and its analysis.

Unit V: Spline, Random numbers, Generating discrete and continuous random variables, Multiple Regression, Variance reduction techniques, Statistical validation techniques, Markov chain, Monte Carlo methods and applications.

Text Book

1. Barnes, Belinda & Fulford, Glenn R., Mathematical Modelling with Case Studies, Using Maple and MATLAB, 3rd edition, CRC Press, Taylor & Francis Group 2015.
2. J. N. Kapur, Mathematical Modeling, New Age International 2005.

Reference Books:

1.Albright B., Mathematical Modeling with Excel, Jones and Bartlett Publishers 2010.
2. F. R. Marotto, Introduction to Mathematical Modeling using Discrete Dynamical Systems, Thomson Brooks/Cole 2006.
3. Willy, Mathematical modelling and simulation: introduction for scientist and engineers, , Kai Velten 2008.

MATH 301: AUTOMATA THEORY (4 Credits)

Course Objectives:

1. To introduce finite state automata – deterministic and non-deterministic.
2. To learn the concept of grammars and regular expressions and their relations.

	Course Outcome
CO 1	To introduce the concepts of finite state automata – deterministic and non-deterministic
CO 2	To familiarize the concept of grammars and regular expressions and their relations
CO 3	In addition, to introduce context free grammars, Pushdown automata and their relations

UNIT I (Sections 1.5, 2.1-2.3**) :** Alphabets, strings, and languages. Finite Automata deterministic and non-deterministic finite automata - Properties of transition functions - The equivalence of DFA and NFA.

UNIT II (Sections 3.1,3.2,3.4**):** Regular expressions, finite automata and regular expressions – algebraic laws for regular expressions.

UNIT III (Sections 4.1,4.2**):**Regular languages and their relationship with finite automata, pumping lemma for regular languages - closure properties of regular languages.

UNIT IV (Sections 5.1.5.2.5.4**):**Context Free Grammars - parse trees - ambiguities in grammars and languages.

UNIT V (Sections 6.1-6.4**):**Pushdown automata - the language of a Pushdown automata – Equivalence of Pushdown automata and context free grammar - deterministic PDA.

Text book

1. John E. Hopcroft, Rajeev Motwani and J.D. Ullman, Introduction to Automata Theory Languages and Computation, Third Edition, Pearson Addison-Wesley, 2006.

Reference books

1. J.A. Anderson, Automata theory with modern applications, Cambridge University Press, 2006.
2. H.R. Lewis, C.H. Papadimitriou, C. Papadimitriou, Elements of the Theory of Computation, 2nd Ed., Prentice-Hall, NJ, 1997.
3. K L P Mishra and N Chandrasekaran, Theory of Computer Science Automata, Languages and Computation, Third Edition, Prentice Hall India, New Delhi, 2006.

MATH 302 :VECTOR ANALYSIS

Course Objectives:

1. To learn about the geometry of curves and surfaces in R^3.
2. To learn curl of a vector field and the divergence of a scalar field.

	Course Outcome
CO 1	To learn about some applications of vector analysis to other branches of sciences
CO 2	To learn about evaluating line and surface integrals over curves and surface respectively
CO 3	To learn about integral theorems in vector analysis.

Unit I (Sections: 1.1-1.6 and 4.1-4.4) **:** Vectors in the plane and space- The inner product and the distance-The cross product and the planes-Curves in the plane and space-Tangents, velocity and speed-Arc length- Vector fields-flow lines-Divergence and curl

Unit II (Sections: 6.1, 6.2**) :** Line Integrals-Line integrals of gradient fields-Independence of parametrization-Line integrals along geometric curves- Work done by a force field-parametrized surfaces- tangent plane.

Unit III (Sections: 6.3, 6.4**) :** Area of a surface-Integral of a scalar function over a surface-Surface integral-The surface integral for Graphs-Surface integral for fluid flow-Area of a shadow.

Unit -IV (Sections: 7.1, 7.2**):** Green's Theorem-Area of a region in Green's Theorem-Vector form of Green's theorem-Gauss Divergence Theorem in the plane-Stokes Theorem for graphs-Circulation and curl.

Unit-V (Sections: 7.3, 7.4**) :** Gauss Theorem-Divergence and Flux-Path independence and the Fundamental Theorem of Calculus-Conservation of vector fields-Curl and gradient-Cross derivative test in the plane-Antiderivative of vector fields-Divergence and Curl.

Text Book: J.E Marsden, A.J Tromba, and A. Weinstein, Basic Multivariable calculus, Springer, 2004.

Reference Books

1. Howard Anton, Irl Bivens, Stephens Davis, Calculus 10e, Wiley India.
2. James Stewart, Calculus, Early Transendentals, 7e CENGAGE India.
3. George B. Thomas, Maurice D Weir, Joel Hass, Frank R Giordono, Thomas calculus 11e, Pearson India.

NEP MINOR COURSES

[to other departments STAT & PHY, etc….]

Minor: MATH-121: BASIC CALCULUS (4 CREDITS)

Course Objectives:

1. Able to Analyze the Derivatives of functions.
2. To understand the idea of applications of Derivatives

	Course Outcome
CO 1	To solve Asymptotes, concavity & convexity point of inflexion
CO 2	Able to solve differentiation using Leibnitz rule
CO 3	To determine the Exponent and Logarithmic functions

Unit I:

Quick review of Derivative of some familiar functions Application of Derivatives - Increasing decreasing functions - Maxima minima-Error –Approximation- Optimization-Newton method- Mean value theorems.

Unit II:

Asymptotes- Test of concavity& convexity point of inflexion- Multiple point training curves in Cartesian & Polar co-ordinates. Successive differentiation- Leibnitz rule- Problems and examples.

Unit III:

Definite integrals - Properties of definite integrals - Integral as the limits of a sum- Evaluation of integrals- Area and the mean value theorem-The fundamental theorem(without proof)- Substitution in definite integrals.

Unit IV:

Integration by parts (theorem and examples) – Integration of rational fractions-Reduction formulas.

Unit V:

Areas between curves- Finding volume by slicing- Volumes of solids of revolution - Disk and washers- Cylindrical shell- Lengths of plane curves- Areas of surface of revolution.

Text Book

2. George B.Thomas, Maurice D.Weir and Joel Hass, Thomas' Calculus 12th Edition, Pearson Education, 2015.

Reference Books

6. Richard Courant and Fritz John, Introduction to Calculus and Analysis, Vol.I, Springer 1999.
7. Serge Lang A First course in Calculus 5th edition, Springer, 1999.
8. N. P. Bali, Integral Calculus, Laxmi Publications, Delhi 1991.
9. Richard Courant and Fritz John, Introduction to Calculus and Analysis, Volumes I & II Springer, SIE, 2004.
10. Serge Lang A First course in Calculus 5th edition, Springer, 1999.

Minor: MATH-122: BASIC ALGEBRA AND THEORY OF EQUATIONS
(4 CREDITS)

Course Objectives:

1. To introduce the idea of matrices and to learn about the algebra of matrices
2. To solve system linear equations using matrix Theory

	Course Outcome
CO 1	To learn the relation between the co-efficient and roots of polynomial equations.
CO 2	To learn various methods for solving polynomial equations and study the nature & position of roots.
CO 3	Analytic Methods for solving the polynomial equation of degrees 3 & 4.

Unit I: (Sections 1.1, 1.2, 1.3,1.4,1.5 of [1])

Linear systems - Matrices - Dot product and Matrix multiplication - Properties of Matrix operation, Matrix transformations.

Unit II: (Sections 1.6,1.7,1.8[1])

Solutions of Linear systems of equations - Row echelon from reduced row echelon form – Polynomial interpolation - The inverse of a Matrix. - Linear Systems and inverses - LU- Factorization Method.

Unit III: (Sections 5.1,5-2,.5.3 of [2])

Division algorithm - Relation between roots and coefficients - Sum of the powers of the roots.

Unit IV: (section 5.4,5.5,5.6 ,5.7 of [2])

Reciprocal equations - Transformation of equations: - Multiple roots - Nature of position of roots - Sturm's Theorem.

Unit V: (Sections 5.8,5.9,5.10 of [2])

Cardan's Method for solving Cubic equations – Ferrari's Method for solving biquadratic equations - New Newton's Method- Horner's Method

Text Books

1. Bernard Kolman Drid R. Hill, Introductory Linear Algebra, (8e),Pearson India (2011)
3. S. Arumugam and A Thangaand Isaac, Set Theory Number System and Theory of Equations, New Gamma publishing house(1997.).

References:

1. Theory of Equations, Hari Kishan, Atlantic Publishers, 2022

2.Theory of Equations, Lalji Prasad, New Revised Edition, 2016

Minor: MATH-221: FUNDAMENTALS OF REAL ANALYSIS
(4 CREDITS)

Course Object:

1. To study the importance of the lub property of the real number system
2. To study the property of convergence sequence

CO 3	To learn some applications of differentiability of functions
CO 4	To introduce the Riemann theory of integration and the fundamental theorem of calculus
CO 5	To learn about pointwise and uniform convergences of sequence of functions

Unit I:[Sections: 3.1, 3.2, 3.3, 3.4]

Convergent sequence Examples – convergent sequences – Limit Theorems – Monotoriesequences Bolzano – Weinerstrars Theorem.

Unit II: [Sections: 3.7, 9.2, 9.3]

Infinite Series – The Cauchy criterion - Examples - Comparison Test - Limit Comparison Test - The Canchy Condensation Test - Absolute Convergence - The root Test – The ratio Test - The Integral Test- Alternating Serier Test - Abel's Test.

Unit III: [Sections: 4.1 4.2, 4, 3].

Limits of function – Examples – Sequence version of the limit of a function - Limit Theorems -One-sided limits.

Unit IV: [Sections: 5.1,5-2, 5·3]

Continuous functions - Examples – Algebra - Continuous functions on intervals - Continuous functions - Intervals Maximum Minimum Theorem – Location of Roots Theorem – Bolzanos Intermediate value theorem

Unit V: [Sections: 6.1,6.2,6.4]

Differentiable functions - Algebra of differentiable functions – Chain Rule - Interior Extremum Theorem - Rolle's Theorem -Mean value Theorem - First derivative Test - Darboux's Theorem - Taylor's Theorem.

Text book:

R. G. Bartle and D. R. Sherbert, Introduction to Real Analysis 4e Wiley India, 2016.

Reference Books

1. Richard R Goldberg, Methods of Real Analysis, Oxford and IBH Publishing Co. Pvt Ltd, New Delhi, Indian Edition 1970.
2. Kenneth A. Ross, *Elementary Analysis: The Theory of Calculus*, springer, 2e (2013).

Minor: MATH-222: INTRODUCTION TO DIFFERENTIAL EQUATIONS
(4 CREDITS)

Course Objectives:

1. To understand ordinary and first order partial differential equations and their applications
2. To understand the first and second order ordinary differential equations and their solution procedures.

	Course Outcome
CO 1	To solve a system of first order ODEs
CO 2	To analyze the stability of a Dynamical System using Differential Equations and their solutions
CO 3	To Solve First Order Partial Differential Equations

Unit I: [Sections 1.5-1.8 from [1]**]**
Exact differential equations- Integrating factors – Linear differential equations- Bernoulli equation – Modeling: Electric circuits – Orthogonal trajectories of curves.

Unit II: [Sections 2.1-2.7 from [1]**]**
Homogeneous linear equations of second order – Second order homogeneous equations with constant coefficients – Case of complex roots- Complex exponential function – Differential operators – Modeling: Free oscillations – Euler-Cauchy equation – Existence and uniqueness theory – Wronskian.

Unit III: [Sections 2.8-2.10, 2.13, 2.14 from [1]]
Non homogeneous equations – Solution by undetermined coefficients – Solution by variation of parameters – Modeling of electric circuits – Higher order linear differential equations – Higher order homogeneous equations with constant coefficients.

Unit IV: [Sections 3.0-3.4 from [1]]
Introduction: vectors, matrices, eigenvalues – Introductory examples – Basic concepts and theory – Homogeneous systems with constant coefficients, phase plane, critical points – Criteria for critical points, Stability.

Unit V: Chapter 1 from [2]
Non-linear first order PDEs : Compatible systems- Solutions of Quasi linear equations
Charpit's method - Special Types of Charpits Method,

Text Book

1. Erwin Kreyszig, Advanced Engineering Mathematics, 8th Edition, John Wiley & Sons, 1999.
2. K. Shankara Rao, Introduction to Partial Differential Equations, PHI Publications,
3rd Edition. 2011. – Chapter 1

Reference Books

1. George F. Simmons, Differential Equations, Tata McGraw-Hill, New Delhi, 1972.
2. Boyce and Di Prima, Differential Equations and Boundary Value Problems, Wiley,10th edition 2012.
3. Earl A. Coddington, An Introduction to Ordinary Differential Equations, Prentice Hall of India Private Ltd, 1991.

Minor: MATH-321: CALCULUS OF SEVERAL VARIABLES
(4 CREDITS)

Course Objectives:

1. To learn about differentiation, partial differentiation and to calculate directional derivatives and gradients
2. To learn about maxima and minima of two and more variables.

	Course Outcome
CO 1	To apply the double and triple integrals to find volume and area of curves
CO 2	To apply line and surface integrals for computing over curves and surface
CO 3	To learn about integral theorems in vector calculus

Unit I: [Sections: 14.1, 14,2,14,3 and 14.4]
Functions of several variables-Level set and graphs-Limit and continuity-Two path test for nonexistence of a limit-Partial derivatives-The chain rule..

Unit II: **[Sections: 14.5, 14.6, 14.7 and 14.8]**
Directional derivatives and gradient vectors- Gradients and tangents to level curves- Tangent planes and normal lines- Linear approximation- Extreme values and saddle points- Second derivative test for local extrema-Lagrange multipliers.

Unit III: [Sections: 14.10, 15.1 and 15.2]
Taylor's formula for two variables- Double integral over rectangles- Fubini's Theorem for calculating double integrals- Area, moments and centre of mass

Unit IV: [Sections: 15.3, 15.4 and 15.5]
Double integrals in polar form-Changing Cartesian integrals into polar integrals- Finding area in polar coordinates – Triple integrals in rectangular coordinates- Volume in triple integrals – Mass and moments in three dimensions.

Unit V: [**Sections: 15.6 and 15.7**]
Triple integrals in Cylindrical and spherical coordinates- Changing the order of integration in cylindrical and spherical coordinates.

Text Book:
George B. Thomas, Maurice D Weir, Joel Hass , Frank R Giordono, ***Thomas calculus 11e,*** Pearson India.

Reference Books:

1. Howard Anton, Irl Bivens, Stephens Davis, ***Calculus*** 10e, Wiley India.
2. James Stewart, ***Calculus, Early Transendentals,*** 7e CENGAGE India.

Minor: MATH-322: INTRODUCTION TO LINEAR ALGEBRA
(4 CREDITS)

Course Objectives:

1. To understand linear transformations Characteristic roots- Similarity of linear transformations and matrices.

	Course Outcome
CO 1	To understand vector spaces, basis and dimensions
CO 2	To understand Matrices and their Trace- Transpose & Determinants.
CO 3	To understand Inner product and orthogonality

Unit I: [Sections 1.2 to 1.6**]**
Abstract Algebra Concepts – Groups- Subgroups- Fields- examples Vector space- Subspace-linear combinations and systems of linear equations- Linear dependence and linear independence- Basis and dimension.

Unit II: [Sections 2.1 to 2.5**]**
Linear Transformations- Null spaces- Range spaces- Dimension theorem- Matrix representation of linear transformation- composition of linear transformations and Matrix multiplication- Invert ability and Isomorphism- The change of coordinate matrix.

Unit III: [Sections 3.1 to 3.4**]**
Elementary matrix Operations and elementary matrices- The rank of a matrix and matrix inverses- systems of linear equations- Theory and computation

Unit IV: [Sections 4.1 to 4.4 and 5.1 to 5.2, 5.4**]**
Determinants of order 2 and order n- propertie4s of determinants- Important facts about determinants- Eigen values and Eigen vectors- Diagonalizability- Invariant spaces and Cayley- Hamilton theorem.

Unit V: [Sections 6.1, 6.2**]**
Inner products and norms- The Gram-Schmidt orthogonalization process and orthogonal complements.

Text Book

Stephen H. Friedberg, Arnold J. Insel and Lawrence E. Spence, Linear Algebra, 4th Edition,
Printice Hall of India Pvt. Ltd., 2006

Reference Book

1. S. Kumaresan, Linear Algebra Geometric Approach, Prentice Hall of India Pvt. Ltd., 2000.
2. I. N. Herstin, Topics in Algebra, 2nd Edition, John Wiley & Sons, 2003.

Minor: MATH-429: VECTOR CALCULUS (4 CREDITS)

Course Objectives:

1. To learn about curvature and torsion of a space curve.
2. To learn about the fundamental theorems by Green, Stoke and Gauss..

	Course Outcome
CO 1	To apply the double and triple integrals to find volume and area of curves
CO 2	To apply line and surface integrals for computing over curves and surface
CO 3	To learn about integral theorems in vector calculus

Unit I: [Sections: 13.1, 13,2,13,3, 13.4 and 13.5]

Vector functions- Modelling projectile motion- Arc length and the unit tangent vector- Curvature and the unit normal vector- Torsion and the unit binormal vector.

Unit II: **[Sections: 16.1 and 16.2]**

Line integrals- Mass and moment calculations- Vector fields- work, circulation and flux- Gradient vector field- work over a smooth curve- Flow integrals and circulation for velocity fields- Flux across a plane- Flux across a smooth closed curve..

Unit III: [Sections: 16.3 and 16.4]

Path dependence of line integrals – The fundamental Theorem of line integrals- Exact differential forms- Green's Theorem in the plane (normal form and tangential form)-Divergenc(flux density)-The Green's Theorem area formula.

Unit IV: [Sections: 16.5, and 16.6]

Surface area and surface integrals- Orientation- Moments and masses of thin shells- Flux across a surface- Parametrized surfaces- Area of a smooth surface- Parametric surface integral- Finding the center of mass.

Unit V: [**Sections: 16.7 and 16.8**]

The Curl of a vector field- Stoke's Theorem- Conservative fields and Stoke's theorem – The Divergence Theorem- The proof of divergence theorem for special regions- Properties of Curl and divergence.

Text Book:

George B. Thomas, Maurice D Weir, Joel Hass , Frank R Giordono, ***Thomas calculus 11e,*** Pearson India.

Reference Books:

1. Howard Anton, Irl Bivens, Stephens Davis, ***Calculus*** 10e, Wiley India.
2. James Stewart, ***Calculus, Early Transendentals,*** 7e CENGAGE India.

Minor: MATH-430: INTRODUCTION TO COMPLEX ANALYSIS

Course Objectives:

1. To study and learn analytic functions and the theory of power series
2. To understand and learn about the conformal mappings and elementary transformations

	Course Outcome
CO 3	To study and learn line integrals, Cauchy's theorem and Cauchy's integral formula
CO 4	To classify zeros and poles and understand Maximum principle
CO 5	To find residues and evaluate complex integrals and definite integrals using the residue theorem and to represent functions as Taylor and Laurent series

Unit I: [Sections 12.1-12.5;**]** Complex numbers- Complex plane - Polar form of complex numbers- Powers and roots – Derivative- Analytic function - Cauchy- Riemann equations. Laplace's equation - Geometry of Analytic Functions- Conformal mapping.

Unit II: [Sections 12.6-12.9;] Exponential function - Trigonometric functions- Hyperbolic functions – Logarithm- General power - Linear fractional transformation.

Unit III: [Sections 13.1-13.4**]** Line integral in the complex plane - Cauchy's integral theorem - Cauchy's integral formula - Derivatives of analytic functions.

Unit IV: [Sections 14.1-14.4**]** Sequences- Series- Convergence tests - Power series - Functions given by power series - Taylor series and maclaurin Series

Unit V: [Sections 15.1-15.4**]** Laurent series - Singularities and zeros, Infinity - Residue integration method evaluation of real integrals.

Text Book:

Erwin Kreyszig, Advanced Engineering Mathematics, 8th Edition, John Wiley & Sons, 1998.

Reference Books

1. L. Ahlfors, Complex Analysis, McGraw-Hill International Edition, 1979.
2. R.V. Churchill, Complex Variables and Applications, 4th Edition, Mc Graw –Hill, 1948.
3. A.Mood, F.Graybill, and D.Boes, *Introduction to the Theory of Statistics*, Tata McGraw Hill (Third Edition) 2008.
4. George Grätzer, Lattice Theory: Foundation, Springer Basel AG, 2011.

MATHEMATICS Syllabi
for B. Tech Programs of
Computer Science, Banking Technology, Electronics, Green Energy and Nano Science Departments

MATHE 111	Mathematics-I	Sem- 1	3L:1T:0P:4 C

Course Objective: T*o comprehend the mathematical concepts of matrices, ordinary differential equations, multivariablecalculus and problem-solving.*

Course Contents:

MODULE I LINEAR ALGEBRA(MATRICES) : Rank of a matrix - Consistency of a system of linear equations - Characteristic equation of a matrix - Eigen values and Eigen vectors - Properties of Eigen values and Eigen vectors - Cayley-Hamiltontheorem (excluding proof)- Verification- Application (Finding Inverse and Power of a matrix)- Diagonalization of a matrix by orthogonal and similarity transformation- Quadratic form – Nature of Quadratic Form- Orthogonal reduction of quadratic form to canonical form.

MODULE II ORDINARY DIFFERENTIAL EQUATIONS : Differential Equations of First Order- Exact equations- Leibnitz's linear equations- Bernoulli's equation- Equations solvable for p- Clairaut's equation- Differential equations of Higher order- Linear differential equations of higher order with constant coefficients- Euler's linear equation of higher order with variable coefficients- Method of variation of parameters.

MODULE III MULTIVARIABLE CALCULUS (DIFFERENTIATION) : Partial differentiation- Partial derivatives of first order and higher order- Partial differentiation of implicit functions- Euler's theorem on homogeneous functions - Total derivative - Jacobian Properties - Taylor's series for functions of two variables- Maxima and minima of functions of two variables.

MODULE IV MULTIVARIABLE CALCULUS (MULTIPLE INTEGRALS) : Double integration (Cartesian form and Polar form)-constant limits- variable limits- over the region R- Changeof variables in double integrals (Cartesian to polar)- Appli- cation of double integral- Area by double integration- Change of Order of Integration- Triple Integration (Cartesian- Spherical and Cylindrical)- constant limits- variable limits- over the region R- Application of triple integral- Volume by triple integration.

MODULE V MULTIVARIABLE CALCULUS (VECTOR CALCULUS) : Vector Differential Operator- Gradient - Properties - Directional derivative - Divergence and curl Properties and relations- Solenoidal and Irrotational vector fields - Line integral and Surface integrals - Integral Theorems (excluding Proof) - Green's theorem - Stoke's theorem - Gauss divergence theorem.

Text Books:

1. Veerarajan T., "Engineering Mathematics - I & II ", Tata McGraw-Hill, New Delhi, 2014 &; 2015.
2. Dr. M.K. Venkataraman, "Engineering Mathematics – Volume I and Volume II", The NationalPublishingCompany, Chennai 2008.

References:

1. Grewal B.S., "Higher Engineering Mathematics", Khanna Publishers, New Delhi, 43rd Edition, 2014.
2. Bali N.P and Manish Goyal., "A Text Book of Engineering Mathematics", Laxmi Publications(P) Ltd,2011.
3. Erwin Kreyszig, "Advanced Engineering Mathematics", John Wiley & Sons, New Delhi, 9thEdition, 2011
4. Ramana B.V., "Higher Engineering Mathematics", Tata McGraw-Hill, New Delhi, 2010.

ONLINE / NPTEL Courses:

1. Differential equations for engineers: https://nptel.ac.in/courses/111106100
2. Calculus of Several Real Variables: https://nptel.ac.in/courses/111104125
3. Engineering Mathematics - I: https://nptel.ac.in/courses/111105121
4. Matrix Analysis with Applications: https://nptel.ac.in/courses/111107112

MATHE 121	Mathematics- II	Sem-2	3L:1T:0P:4C

Course Objective:

- *To formulate and solve partial differential equations, Laplace, Fourier transforms within the engineeringdomain.*

Course Contents:

MODULE I PARTIAL DIFFERENTIAL EQUATIONS (12 Hrs)

Formation of partial differential equations, Solutions of standard types of first order partial differential equations, Lagrange s linear equation, Linear partial differential equations of second and higher order with constant coefficients of both homogeneous and non-homogeneous types.

MODULE II LAPLACE TRANSFORM (12 Hrs)

Existence conditions, Transforms of elementary functions , Properties, Transform of unit step function and unitimpulse function , Transforms of derivatives and integrals , Transforms of Periodic Functions , Initial and final value theorems.

MODULE III INVERSE LAPLACE TRANSFORM (12 Hrs)

Inverse Laplace Transforms Properties, Convolution theorem, Application - Solution of ordinary differential equations with constant coefficients - Solution of simultaneous ordinary differential equations.

MODULE IV FOURIER TRANSFORM (12 Hrs)

Fourier Integral theorem (statement only) , Fourier transform and its inverse, Properties: Fourier sine and cosine transforms, Properties, Convolution and Parseval s identity.

MODULE V FOURIER SERIES (12 Hrs)

Dirichlet s conditions , Expansion of periodic functions into Fourier series- Change of interval, Half-range Fourier series, Root mean square value - Parseval s theorem on Fourier coefficients, Harmonic analysis.

Text Books:

1. Grewal B.S, "Higher Engineering Mathematics", Khanna Publishers, New Delhi, 43rd Edition, 2015.
2. Veerarajan T, "Transforms and Partial Differential Equations", Tata McGraw-Hill, New Delhi, 2012.

References:

1. Bali N.P and Manish Goyal., "A Text Book of Engineering Mathematics", Laxmi Publications(P) Ltd,2011.
2. Erwin Kreyszig, "Advanced Engineering Mathematics", John Wiley & Sons, New Delhi, 9th Edition,2011.
3. Ramana B.V., "Higher Engineering Mathematics", Tata McGraw-Hill, New Delhi, 2010.

ONLINE / NPTEL Courses:

1. Laplace Transform: https://nptel.ac.in/courses/111106139
2. Partial Differential Equations: https://nptel.ac.in/courses/111101153
3. Advanced Engineering Mathematics: https://nptel.ac.in/courses/111107119

MATHE 122	Subject Title APPLIED LINEAR ALGEBRA – SEM 2	L T P C 3 0 0 3

Learning Objectives:

1. To learn the properties of a linear transformation and to analyze a linear system of equations
2. To solve linear equations and understand the applications of linear algebra in engineering

Learning Outcome:

On completion of the course, the students will be able to:

1. Solve a linear system of equations using direct and iterative methods and Eigenvalue problems
2. Formulate linear equations for real life problems and solve them

Components of Teaching Type: *Classroom Based Teaching*

Unit I: Vector spaces

Vector spaces – Subspaces – Linear combinations and linear system of equations. Linear independence and Linear dependence – Basis and Dimension

Unit II: Linear Transformations

Linear Transformation – Null space, Range space - Dimension theorem - Matrix representations of Linear Transformations. Eigenvalues and Eigenvectors of a linear transformation – Diagonalization of linear transformations – Application of diagonalization in a linear system of differential equations.

Unit III: Orthogonal vectors

Inner Product Spaces –Norms - Orthogonal vectors – Gram Schmidt orthogonalization process – Least Square Approximations

Unit IV: Linear system of equations

Solution of linear system of equations – Direct method: Gauss elimination method – Pivoting – Gauss Jordan method -LU decomposition method – Cholesky decomposition method Iterative methods: Gauss-Jacobi and Gauss-Seidel – SOR Method

Unit V: Eigenvalue problems

Eigenvalue Problems: Power method – Inverse Power method - Jacobi's rotation method Generalized Inverses QR decomposition - Singular Value Decomposition method

Text and Reference Books:

1. **Stephen H. Friedberg, Insel A.J. and Spence L.E., "Linear Algebra", 4th. Edition, Prentice - Hall of India, New Delhi, 2003.**
2. M.K.Jain, S.R.K.Iyengar, R.K.Jain, "Numerical Methods for Scientific and Engineering Computation", New Age International (P) Limited, New Delhi, 2003.
3. Strang G., "Linear Algebra and its Applications", Thomson (Brooks/Cole), New Delhi, 2005.
4. Kumaresan. S., "Linear Algebra – A Geometric Approach", PHI, New Delhi, 2010.
5. Faires J.D. and Burden R., "Numerical Methods", Brooks/Cole (Thomson Publications), New Delhi, 2002.

MATHE 211	Subject Title DISCRETE MATHEMATICS SEM-3	L T P C 3 1 0 4

Learning Objectives:

1. To develop a foundation of set theory concepts and explore a variety of various mathematical structures by focusing on mathematical objects, operations, and resulting properties
2. To develop formal logical reasoning techniques and concept of relation through various representations

Learning Outcome:

On completion of the course, the students will able to:

1. *Construct* proofs using direct proof, proof by contraposition, proof by contradiction, and proof by cases.
2. Demonstrate the ability to solve problems using counting techniques and combinatory in the context of discrete probability.

Components of Teaching Type: Classroom based Learning

Unit I: Set Theory : Introduction, Combination of sets, Multisets, Ordered pairs. Proofs of some general identities on sets. Relations: Definition, Operations on relations, Properties of relations, Composite Relations, Equality of relations, Recursive definition of relation, Order of relations. Functions: Definition, Classification of functions, Operations on functions, Recursively defined functions, Growth of Functions, Natural Numbers: Introduction, Mathematical Induction, Variants of Induction, and Induction with Nonzero Base cases. Proof Methods, Proof by counter – example, Proof by contradiction.

Unit II: Algebraic Structures

Definition, Groups, Subgroups and order, Cyclic Groups, Cosets, Lagrange's theorem, Normal Subgroups, Permutation and Symmetric groups, Group Homomorphisms, Definition and elementary properties of Rings and Fields, Integers Modulo n.

Unit III: Partial order sets

Definition, Partial order sets, Combination of partial order sets, Hasse diagram. Lattices: Definition, Properties of lattices – Bounded, Complemented, Modular and Complete lattice. Boolean Algebra: Introduction, Axioms and Theorems of Boolean algebra, Algebraic manipulation of Boolean expressions. Simplification of Boolean Functions, Karnaugh maps, Logic gates, Digital circuits and Boolean algebra.

Unit IV: Propositional Logic

Proposition, well-formed formula, Truth tables, Tautology, Satisfiability, Contradiction, Algebra of proposition, Theory of Inference Predicate Logic: First order predicate, well-formed formula of predicate, quantifiers, Inference theory of predicate logic.

Unit V: Trees

Definition, Binary tree, Binary tree traversal, Binary search tree. Graphs: Definition and terminology, Representation of graphs, Multigraphs, Bipartite graphs, Planar graphs, Isomorphism and Homeomorphism of graphs, Euler and Hamiltonian paths, Graph coloring Recurrence Relation & Generating function: Recursive definition of functions, Recursive algorithms, Method of solving recurrences. Combinatory, Introduction, Counting Techniques, Pigeonhole Principle.

Text Books:

1. **Elements of Discrete Mathematics – Liu and Mohapatra, McGraw Hill Publications, 2017**
2. **Discrete Mathematical Structures – B. Kolman, R.C. Busby, and S.C. Ross, PHI Publications, Third edition, 2016**
3. Discrete Mathematical Structures with Application to Computer Science – Jean Paul Trembley and R Manohar, McGraw-Hill Publications, 2017
4. Discrete and Combinatorial Mathematics – R.P. Grimaldi, Addison Wesley, 2006
5. Discrete Mathematics and Its Applications, Kenneth H. Rosen, McGraw-Hill 8th edi, 2021

MATHE 212	Numerical Techniques	Sem-3	2L:0T:2P:3C

Course Objectives:

- *Cover certain basic, important computer oriented numerical methods for analyzing problems that arise in engineering and physical sciences.*
- *To obtain solutions to a few problems that arise in their respective engineering courses.*
- *To Impart skills to analyze problems connected with data analysis,*
- *Solve ordinary and partial differential equations numerically*

Course Contents:

MODULE I Interpolation 9 Hours

Interpolation by polynomials, error of the interpolating polynomial, piecewise linear and cubic spline interpolation.

MODULE II Numerical Integration 9 Hours

Numerical integration, Simpson rule, composite rules, error formulae, Gaussquadrature.

MODULE III System of Linear Equations 9 Hours

Solution of a system of linear equations, implementation of Gaussian elimination and Gauss- Seidel methods, partial pivoting, row echelon form, LU factorization, Cholesky's method, ill- conditioning, norms.

MODULE IV Non-linear Equation 9 Hours

Solution of a nonlinear equation, bisection and secant methods. Newton-Raphson method, rateof convergence, solution of a system of nonlinear equations.

MODULE V Numerical solution of Ordinary Differential Equations

Euler and Runge-Kutta methods, multistep methods, predictor-corrector methods, order of convergence, finite difference methods, numerical solutions of elliptic, parabolic, and hyperbolic partial differential equations. Eigenvalue problem, power method, QR method, Gershgorin‟s theorem. Exposure to software packages.

Text Books:

1. M. K. Jain, S. R. K. Iyengar and R. K. Jain, Numerical Methods for Scientific and Engineering,2012, New Age International Ltd., 6th Edition.
2. R.L. Burden and J. D. Faires, Numerical Analysis, , 2012, 4th Edition, Brooks Cole.

Reference Books:

1.E. Kreyszig, Advanced engineering mathematics (8th Edition), John Wiley (1999).

2.Reena Garg, Advanced Engineering Mathematics, Khanna Book Publishing (2022).

3.R. Agor, Elements of Mathematical Analysis, Khanna Publishing House, 2015.

Course Outcomes:

At the end of this course students will demonstrate the ability to

1. Understand different numerical integration techniques, and numerically solve differential equations.
2. Perform various matrix computations and solve simultaneous linear equations.
3. Find roots of a transcendental equation using different methods.
4. Implement different interpolation schemes.
5. Understanding of Eigenvalue problem and power method.

MATHE 213	Mathematics – III	Sem-3	3L:1T:0P:4C

Course Objectives:

• The course aims to equip students with the ability to apply mathematical concepts to Engineering problems.

Unit – I: Probability (12 hrs)

Sample space and Events, Axioms of Probability, Conventional Probability, Bayes' Theorem, Independent Events, Random Variables, Discrete and Continuous Random Variables – Probability Mass Function – Probability Density Function – Cumulative Distribution Function – Expectation and Variance, Standard probability Distribution – Bernoulli, Binomial, Poisson, Geomtric and Normal Distributions.

Unit – II: Statistics and applications (12 hrs)

Measures of Central Tendency – Mean- Median-Mode; Measure of Dispersion – Range – Variance-Standard Deviation; Moments, Skewness and Kurtosis, Correlation and Regression – Rank Correlation
Curve Fitting by the Method of Least Square, Fitting of Straight lines, Second degree parabolas and more general curves. Test of Significance: Large sample test for single proportion, Difference of proportions, Single Mean, Difference of Means and Difference of Standard Deviations

Unit -III - Application of PDEs (16 hrs)

Second-order linear PDE and their classification, Initial and boundary conditions, D'A lembert's solution of the wave equation; Duhamel's principle for one dimensional wave equation. Heat diffusion and vibration problems, Separation of variables method to simple problems in Cartesian coordinates. The Laplacian in plane, cylindrical and spherical polar coordinates, solutions with Bessel functions and Legendre functions. One dimensional diffusion equation and its solution by separation of variables.

Unit IV - Numerical Methods (10 hrs)

Numerical integration, Simpson rule, composite rules, error formulae, Solution of a system of linear equations, implementation of Gaussian elimination and Gauss- Seidel methods, Cholesky's method, Solution of a nonlinear equation, bisection and secant methods. Newton-Raphson method, rate of convergence, solution of a system of nonlinear equations.

Unit V - Numerical solution to ODE (10 hrs)

Euler and Runge-Kutta methods, multistep methods, predictor-corrector methods, order of convergence, finite difference methods, numerical solutions of elliptic, parabolic, and hyperbolic partial differential equations. Eigenvalue problem, power method, QR method

Text Book:

1. Reena Garg, Engineering Mathematics, Khanna Book Publishing Company, 2022.
2. M. K. Jain, S. R. K. Iyengar and R. K. Jain, Numerical Methods for Scientific and Engineering, 2012, New Age International Ltd., 6th Edition.
3. R.L. Burden and J. D. Faires, Numerical Analysis, 2012, 4th Edition, Brooks Cole.

Reference Books:

1. Reena Garg, Advanced Engineering Mathematics, Khanna Book Publishing Company, 2021.
2. Erwin Kreyszig, Advanced Engineering Mathematics, 9th Edition, John Wiley & Sons, 2006.
3. N.P. Bali and Manish Goyal, A text book of Engineering Mathematics, Laxmi Publications, Reprint, 2010.
4. R. Agor, Elements of Mathematical Analysis, Khanna Publishing House, 2015.

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