SCHOOL OF SCIENCES

(FORMERLY, SCHOOL OF ARCHITECTURE, SCIENCE AND TECHNOLOGY)

YASHWANTRAO CHAVAN MAHARASHTRA OPEN UNIVERSITY

Syllabus:

V151: M.Sc. (Mathematics)

{2023 Pattern}

(Semester 01 to 04)

(Incorporating NEP2020 Recommendations, PG Credit and Curriculum Framework GR dated 16-05-2023)

With effect from Academic Year 2023-24, vide G.R. No. NEP-2022/CR No. 09/VISHI-3/शिकाना, dated 16 May, 2023.

2023

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School of Sciences

Director of the School: Dr. Chetana Kamlaskar

Programme Advisory Committee Members

V151: M.Sc. (Mathematics) {2023 Pattern}

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NEP2020: Programme Structure with Syllabus of all Courses at Semester 01 to 04 were finalized in PAC meeting held on 26th July 2023

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Revised on 31 Aug 2023, 25 Nov2023 for Evaluation Pattern

CONTENTS

V151: M.Sc. (Mathematics) {2023 Pattern}

About the Programme

Programme Code: V151

Programme Name: M.Sc. (Mathematics)

This M.Sc. programme is uniquely designed to impart essential knowledge in all major areas of pure or applied mathematics. This programme offers an exciting opportunity for specialization in mathematics to model and solves different real-life problems. The programme contents of total 04 semesters are a carefully selected blend of theory and practical which prepares students for specialist professional employment, research in academia, and various industries for broader applications. Learner centric curriculum is designed in adherence to the principles of National Education Policy (NEP 2020) to acquire knowledge and skills with valuable experiences through hands-on activities, projects and internships.

Objectives of the Programme

This programme has the following broad objectives:

- To prepare the learners, who will understand and apply the basic as well as advanced principles of mathematics for solving problems from science with an emphasis on applications
- To produce the learners who are well-grounded in the fundamentals of Mathematics with the acquisition of the necessary skills, tools, and techniques required in many applications areas
- To develop an ability to study the conceptual problem and critically analyze, and also promote the use of mathematics in industry and applied sciences
- To provide exposure and motivate students for research in current trends of mathematics

Scope of the Programme

After successful completion of the M.Sc. programme, the learner has ample opportunities to use their mathematical knowledge in different areas:

- Career opportunities in government organizations like Defense Research and Development Organization (DRDO), Indian Space Research Organization (ISRO), research laboratories like Council of Scientific and Industrial Research or government-owned scientific organizations.
- Job positions like Mathematics Specialist, Quantitative Risk Analyst, Treasury Management Specialist, Public sector banking, financial institutions, Engineering or Insurance Sectors, etc.
- Job opportunities in the teaching profession at Science and Engineering colleges, and Universities
- Scope for Higher Studies and find lucrative opportunities in the field of research.

PROGRAMME OUTCOMES

After successful completion of this programme, students will be able to

- Enhance their logical thinking and apply advanced mathematical concepts to solve complex problems.
- Formulate research questions, design experiments or investigations, collect and analyse data, and present their findings in a clear and coherent manner.
- Apply advanced mathematical techniques and tools to analyse and solve challenging problems encountered in mathematics and related fields.
- Formulate mathematical models that represent real-world phenomena, analyse the models using mathematical methods, and interpret the results to make informed decisions or predictions.
- Develop proficiency in utilizing computational tools, software, and programming languages to aid in mathematical analysis, numerical simulations, and data visualization.
- Present complex mathematical concepts, proofs, and research findings to both technical and non-technical audiences.
- Develop a strong foundation for professional growth and lifelong learning in mathematics.

MODE OF EDUCATION

This Programme will be offered in Open and Distance Learning (ODL) Mode as defined in "UGC Open and Distance Learning Programmes and Online Programmes Regulations, 2020" published in the gazette notification by dated 4th Sept 2020 by the UGC as specified below.

> *"Open and Distance Learning Mode means a mode of providing flexible learning opportunities by overcoming separation of teacher and learner using a variety of media, including print, electronic, online and occasional interactive face-to-face meetings with the learners or Learner Support Services to deliver teaching-learning experiences, including practical or work experiences"*

BASIC INFORMATION

1. **Mode of Education**: ODL Mode.
2. **Minimum Programme Duration**: 2 years/ 4 semesters after any B.Sc. with Maths upto Second year/ BA with Maths/ BE/ B.Tech. or equivalent pass
3. **Maximum Programme Duration:** 4 years from the date of admission to the PG programme, also referred as Valid Registration Period.
4. **Learner Support Centers (LSC):** University approved/recognized Senior Science Colleges/ Institutes offering PG Mathematics programme.
5. **Medium of Instruction:** English
6. **Attendance:** Minimum 80% attendance for all type of courses.
7. **Profile of Prospective Students**: In-Service Science Teachers from Schools/ Junior College and Equivalent pass students.

8. **Teaching-Learning:** Total 12 + 3 = 15 working weeks in each semester, where 3-weeks' time duration in each semester for clearing face-to-face counseling session's backlog (if any).
9. **Total Teaching-Learning Support:** Total 2640 Hours including Self-Study during all 4 semesters. 660 Hours (including Self-Study) **during** each semester.
10. **Total Courses:** Total 23 courses (subjects) distributed over Semesters 01 to 04.
11. **Total Credits:** 88 Credits [As per UGC norms 1 Credit means 30 hours of study efforts required to gain learning of particular content of each credit].
12. **Total Courses and Credit Distribution Scheme:**

Semester	**Mandatory Courses(DSC)**			**Elective Courses (DSE)** (4 Credits)	**Other Courses** (4 Credits)/ (6 Credits)	**Total Courses (Credits)**
	Theory		Practical (4 Credits)			
	(4 Credits)	(2 Credits)				
1	2	1	1	1	1 – Research Methodology (4 Credits)	**6** (22 Credits)
2	2	1	1	1	Any one - OJT/ Field Projects (4 Credits)	**6** (22 Credits)
3	2	1	1	1	1- Research Project (4 Credits)	**6** (22 Credits)
4	2	-	1	1	1- Research Project (6 Credits)	**5** (22 Credits)
Total	8 x4= (32 Credits)	3 x2= (6 Credits)	4x4= (16 Credits)	4x4= (16 Credits)	4x3+1x6= (18 Credits)	23 (88 Credits)

13. **Multiple Entry and Multiple Exit**: The multiple entry and multiple exit features open up new opportunities for learners, even if they have stopped or discontinued their study in the middle for a variety of reasons. This feature provides entry options in order to promote flexible learning within the valid registration period (04 years from the date of admission to the PG programme). Learners only have the choice to leave the program at the end of even semester 02, and they have the option to reenter at the start of odd semester 03. Only one exit option and reentry is permissible for MSc programme during stipulated time period.
14. **Exit Option-PG Diploma:** The learner who passes all registered courses of first year (two semesters) of the programme successfully in the examinations and obtains required credits (44 Credits), shall be awarded with Post Graduate Diploma Certificate PGD 9-MAT if learner shall opt for exit. The aggregate performance (SGPA of Semester 01 and Semester 02) and Class in the programme shall be reported on the basis of performance.
15. **PG Degree Certificate**: After successful completion of all courses (semesters 01 to 04) at two year of the programme and obtaining required credits (88 Credits), learner shall be awarded with Post Graduate Degree. The aggregate performance (CGPA of Semester 01 to Semester 04) and Class in the programme shall be reported on the basis of performance.

16. **Equivalence Status**: UGC and DEB recognized and approved [AY 2023 and onwards] with UGC/DEB letter F.No. 1-2/2021 (DEB-I), dated: 02.08.2021, available at https://www.ugc.ac.in/pdfnews/4204139_HEI-Recognition-list-02-08-2021.pdf

ELIGIBILITY AND FEES

<table>
<tr><th>Admission Eligibility</th><th>Certification Eligibility</th><th>Fees per year
Annual Admission Form Amount (AAFA) is payable to university along with admission form at the start of each year.</th></tr>
<tr><td>Any B.Sc. with Maths upto Second year/ BA with Maths/ BE/ B.Tech. or equivalent pass</td><td>V151: Min 40% or better marks in total 23 courses (subjects) of total 88 credits at Semesters 01 to 04.

CGPA:
Aggregate performance and Class in the programme shall be reported on the basis of semesters 01 to 04.

For exit option PGD 9- MAT: Min 40% or better marks in total 12 courses (subjects) of total 44 credits at Semesters 01 to 02.</td><td>
<table>
<tr><th colspan="2">Desc</th><th>INR ₹</th></tr>
<tr><td colspan="2"></td><td>1st yr</td><td>2nd yr</td></tr>
<tr><td colspan="2">Mandatory Fee (MF)</td><td>608</td><td>858</td></tr>
<tr><td rowspan="2">Tuition Fee</td><td>USF</td><td>6000</td><td>6000</td></tr>
<tr><td>LSCF</td><td>6000</td><td>6000</td></tr>
<tr><td colspan="2">End Exam Fee (EEF)</td><td>2000</td><td>2000</td></tr>
<tr><td colspan="2">Total (AAFA)</td><td>14,608</td><td>14,858</td></tr>
</table>
</td></tr>
</table>

PROGRAMME STRUCTURE OF V151:M.SC.(MATHEMATICS){2023 PATTERN}

Year (2 Yr. PG)	Level / Sem.	Major				RM	OJT/ FP	RP	Cum. Cr.
		Mandatory (DSC)	Cr	Elective (DSE)	Cr				
I	6.0/ Sem I	MAT501: Real Analysis **(T)**	4	MAT506: Operations Research **(T)** **OR** MAT507: Numerical Analysis **(T)**	4	RES505: Research Methodology **(T) (4 Cr)**	-	-	22
		MAT502:Abstract Algebra**(T)**	4						
		MAT503: Ordinary Differential Equations **(T)**	2						
		MAT504:Programming in C and Scilab**(P)**	4						
	6.0/ Sem II	MAT509: Topology **(T)**	4	MAT515: Number Theory **(T)** **OR** MAT516: Field Theory **(T)**	4		MAT513: OJT **(4 Cr)** **OR** MAT514:FP **(4 Cr)**	-	22
		MAT510: Linear Algebra**(T)**	4						
		MAT511: Partial Differential Equations**(T)**	2						
		MAT512:LaTex and Programming in SageMath**(P)**	4						
Cum. Cr. For1 Years PG Diploma		**28**		**8**		**4**	**4**	**-**	**44**
Exit option: PG Diploma (44 Credits) after Three Year UG Degree (PGD 9-MAT: Post Graduate Diploma in Mathematics)									
II	6.5/ Sem III	MAT601:Complex Analysis **(T)**	4	MAT606: Discrete Mathematics **(T)** **OR** MAT607: Differential Geometry **(T)** **OR** MAT608: Integral Transforms **(T)**	4		-	MAT605: Research Project **(4 Cr)**	22
		MAT602: Measure and Integration Theory **(T)**	4						
		MAT603:Integral Equations**(T)**	2						
		MAT604:Mathematical Statistics & Combinatorics (**P**)	4						
	6.5/ Sem IV	MAT609:Classical Mechanics**(T)**	4	MAT613:Cryptography**(T)** **OR** MAT614:Topics in Fuzzy Mathematics**(T)** **OR** MAT615:Algebraic Topology**(T)**	4	-		MAT612: Research Project **(6 Cr)**	22
		MAT610:Functional Analysis**(T)**	4						
		MAT611: Programming in Python **(P)**	4						
Cum. Cr. For 2 Years PG Degree		**54**		**16**		**4**	**4**	**10**	**88**
2 Years-4 Sem. PG Degree (88 credits) after Three Year UG Degree									

Abbreviations: Yr.: Year; Sem.: Semester; Cumulative Credits: Cum. Cr. ; T- Theory Course;P- Practical course; TW-Term Work; PW- Project Work

SEMESTERS AND COURSES

Abbreviations of the courses

Mandatory DSC	Discipline Specific Core Course	**Elective DSE**	Discipline Specific Elective Course
RM	Research Methodology	**OJT**	On Job Training: Internship/ Apprenticeship
FP	Field projects	**RP**	Research Project
OE	Open Elective (May be taken from MOOC or may be chosen from other domain of learning to get exposure to interdisciplinary domain)[OE will be offered in Phase Manner]		

SN	Course Category	Code	Course Name	CA	EE	TM	Type	CR	Min %
[Level 6.0] Semester 01: 22 Credits									
01	Mandatory(DSC)	MAT501	Real Analysis	30	70	100	T	4	40%
02	Mandatory(DSC)	MAT502	Abstract Algebra	30	70	100	T	4	40%
03	Mandatory(DSC)	MAT503	Ordinary Differential Equations	15	35	50	T	2	40%
04	Mandatory(DSC)	MAT504	Programming in C and Scilab	50	50	100	P	4	40%
05	RM	RES505	Research Methodology	30	70	100	T	4	40%
Elective (DSE)Courses (Select Any One)									
06	Elective (DSE)	MAT506	Operations Research	30	70	100	T	4	40%
07	Elective (DSE)	MAT507	Numerical Analysis	30	70	100	T	4	40%
[Level 6.0] Semester 02: 22 Credits									
08	Mandatory(DSC)	MAT509	Topology	30	70	100	T	4	40%
09	Mandatory(DSC)	MAT510	Linear Algebra	30	70	100	T	4	40%
10	Mandatory(DSC)	MAT511	Partial Differential Equations	15	35	50	T	2	40%
11	Mandatory(DSC)	MAT512	LaTex and Programming in SageMath	50	50	100	P	4	40%
12	OJT/FP	MAT513 MAT514	Any one OJT or FP OJT FP	50	50	100	TW	4	40%
Elective (DSE)Courses (Select Any One)									
13	Elective (DSE)	MAT515	Number Theory	30	70	100	T	4	40%
14	Elective (DSE)	MAT516	Field Theory	30	70	100	T	4	40%
Exit option: PGD 9- MAT (44 Credits) after Three Year UG Degree									
[Level 6.5] Semester 03: 22 Credits									
15	Mandatory(DSC)	MAT601	Complex Analysis	30	70	100	T	4	40%
16	Mandatory(DSC)	MAT602	Measure and Integration Theory	30	70	100	T	4	40%
17	Mandatory(DSC)	MAT603	Integral Equations	15	35	50	T	2	40%
18	Mandatory(DSC)	MAT604	Mathematical Statistics & Combinatorics	50	50	100	P	4	40%

SN	Course Category	Code	Course Name	CA	EE	TM	Type	CR	Min %
19	RP	MAT605	Research Project	50	50	100	PW	4	40%
Elective (DSE)Courses (Select Any One)									
20	Elective (DSE)	MAT606	Discrete Mathematics	30	70	100	T	4	40%
21	Elective (DSE)	MAT607	Differential Geometry	30	70	100	T	4	40%
22	Elective (DSE)	MAT608	Integral Transforms	30	70	100	T	4	40%
[Level 6.5] Semester 04: 22 Credits									
23	Mandatory(DSC)	MAT609	Classical Mechanics	30	70	100	T	4	40%
24	Mandatory(DSC)	MAT610	Functional Analysis	30	70	100	T	4	40%
25	Mandatory(DSC)	MAT611	Programming in Python	50	50	100	P	4	40%
26	RP	MAT612	Research Project	75	75	150	PW	6	40%
Elective (DSE)Courses (Select Any One)									
27	Elective (DSE)	MAT613	Cryptography	30	70	100	T	4	40%
28	Elective (DSE)	MAT614	Topics in Fuzzy Mathematics	30	70	100	T	4	40%
29	Elective (DSE)	MAT615	Algebraic Topology	30	70	100	T	4	40%

GRADING SYSTEM

1. "**Absolute Grading**": the marks are converted to grades based on pre-determined class intervals.
2. "**Letter Grade**": It is an index of the performance of students in a said programme. Grades are denoted by letters O, A+, A, B+, B, C, P and F.
3. "**Grade Point**": It is a numerical weight allotted to each letter grade on a 10-point scale. Grade Point shall be "0 (Zero)" for Letter Grade "Ab" and "F". The marks scored by the examinee shall be converted into grade points by dividing the marks scored in the aggregate and dividing the resulting number by maximum marks, multiplying the result by ten, retaining the integer part (ignore the fractional part). Thus, if a person has secured 56 marks out of 100 marks in aggregate for a course, we get (56/100) x 10 which is 5.6. Ignoring the fraction, we get 5 as the grade point.

Marks Obtained out of 100	Grade Point	Semester GPA/Programme CGPA Semester/ Programme	% of Marks	Alpha-Sign / Letter Grade Result
90 –100	10	9.00 – 10. 00	90.0 - 100	O (Outstanding)
80 – 89.99	9	8.00 - < 9.00	80.0 - < 90.0	A+ (Excellent)
70 – 79.99	8	7.00 - < 8.00	70.0 - < 80.0	A (Very Good)
60 – 69.99	7	6.00 - < 7.00	60.0 - < 70.0	B+ (Good)
55 – 59.99	6	5.50 - < 6.00	55.0 - < 60.0	B (Above Average)
50 – 54.99	5	5.00 - < 5.50	50.0 - < 55.0	C (Average)
40 – 49.99	4	4.00 - < 5.00	40.0 - < 50.0	**P (Pass)**
0 – 39.99	0	Below 4.00	**Below 40**	**F (Fail)**
		Ab (Absent)	-	**Absent**

4. "**Credit Point**": It is the product of grade point and number of credits for a course.

5. "**Semester Grade Point Average (SGPA)**": It is a measure of performance of work done in a semester. It is the ratio of sum of the product of the number of credits with the grade points scored by a student in all courses taken by a student and the sum of number of credits of all the courses undergone by a student:

$$SGPA\ (S_i) = \frac{\sum C_i G_i}{\sum C_i}$$

Where, C_i: $No.\ of\ Credits$ &G_i: $Grade\ Points\ scored\ in\ a\ course$

It shall be expressed up to two decimal places.

6. "**Cumulative Grade Point Average (CGPA)**": It is a measure of overall cumulative performance of a student over all semesters. The CGPA is the ratio of total credit points secured by a student in various courses in all semesters and the sum of the total credits of all courses in all the semesters. The CGPA is also calculated in the same manner taking into account all the courses undergone by a student over all the semesters of a programme.

$$CGPA = \frac{\sum C_i S_i}{\sum C_i}$$

Where, S_i**is the SGPAof the ith semester &** C_i**is the total number of credits in that semester.**

It shall be expressed up to two decimal places.

7. "**Transcript or Grade Card or Certificate**": Based on the grades earned, a grade certificate shall be issued to all the registered students after every semester. The grade certificate will display the course details (code, title, number of credits, grade secured) along with SGPA of that semester and CGPA earned till that semester.

8. **"Evaluation Pattern**": As per NEP2020, the 'Evaluation Pattern' of the Post graduate Programme consists of the following components:

Course Type	Number of Credits	Continuous Assessment (CA)	End Examination (EE)	Total Marks 'TM' = (CA+EE)	Minimum Passing %
Theory(T)	4	30	70	100	minimum 40% in CA, EE and (CA + EE) shall be essential for each course to pass
Theory (T)	2	15	35	50	
Practical (P)	4	50	50	100	
OJT/Field Project (FP)	4	50	50	100	
Research Project (RP)	4	50	50	100	
Research Project(RP)	6	75	75	150	

EVALUATION PATTERN

[CA and EE Evaluation Pattern as per the Minutes of the Meeting of the NEP Cell Dated 21.11.2023]

SN	Type of Course	Continuous Assessment (CA)	End Examination (EE)
1	Theory (T) 4 Credit 100 Marks CA: 30% EE: 70%	Each student is required to attempt total 02 (Two) "Continuous Assessments (CAs)" for each course of each Semester, as per the following details: 1. CA01: 'Continuous Assessment 01 (CA01)' on Credit 01 to Credit 04 of each course, consists of • 2 (Two) 'Short Answer Questions (SAQs)', each carrying 05 Marks, on Credit 01 and Credit 02 **and** • 1 (One) 'Long Answer Question (LAQ)' of 10 Marks, on Credit 03 and Credit 04. LAQ may consist of sub-questions. **CA01**: On Credit 01 to Credit 04, of Marks = (5x2 + 10) = **20 Marks** 2. CA02: 'Continuous Assessment 02 (CA02)' on Credit 01 to Credit 04 of each course, consists of • A test containing total **10** (Ten) 'Objective Type Questions, ' 05 (Five) on Credit 01 and Credit 02, and 05 (Five) on Credit 03 and Credit 04. Each 'Objective Type Question' of 1 Mark. **CA02**: On Credit 01 to Credit 04, of Marks = **10 Marks** 3. Maximum number of attempts for **CA,** during each semester : Single attempt only 4. **Total Marks**: **30** Marks	1. Student is required to answer **05 'VSAQs' out of 06 'VSAQs'**, each carrying 03 Marks, on Credit 01 to 04, for total 15 Marks. One VSAQ will be on each Credit. 2. Student is required to answer **05 'SAQs' out of 06 'SAQs'**, each carrying 05 Marks, on Credit 01 to 04, for total 25 Marks. One SAQ will be on each Credit. 3. Student is required to answer **01 'LAQ' out of 2 LAQs,** of 10 Marks on Credit 01 and Credit 02, for total 10 Marks. LAQ may consist of sub-questions. 4. Student is required to answer **01 'LAQ' out of 2 LAQs,** of 10 Marks on Credit 03 and Credit 04, for total 10 Marks. LAQ may consist of sub-questions. 5. Student is required to answer **01 'LAQ' out of 2 LAQs,** of 10 Marks on Credit 01 to Credit 04, for total 10 Marks. LAQ may consist of sub-questions. 6. Number of attempts: Till Valid Registration Period (VRP) only 7. Marks: 70 Marks 8. Duration: 150 minutes

<table>
<tr><th>SN</th><th>Type of Course</th><th colspan="2">Continuous Assessment (CA)</th><th colspan="2">End Examination (EE)</th></tr>
<tr><td></td><td></td><td colspan="4"><table>
<tr><td>SN</td><td>Description</td><td colspan="2">Evaluation of End Examination(EE)</td><td>Marks</td></tr>
<tr><td rowspan="3">1</td><td rowspan="3">Question Types</td><td colspan="2">Very Short Answer Question (VSAQ) on each Credit</td><td>03 Marks</td></tr>
<tr><td colspan="2">Short Answer Question (SAQ) on each Credit</td><td>05 Marks</td></tr>
<tr><td colspan="2">On each Credit, either Single Long Answer Question (LAQ) or LAQ contains sub-questions (a), (b) and so on.</td><td>10 Marks</td></tr>
<tr><td>2</td><td>Grand Total Marks</td><td colspan="2">Total five Questions in EE Question paper based on:
Credit 01 to 04 : 05 VSAQs out of 06 VSAQs (15 Marks)
Credit 01 to 04 : 05 SAQs out of 06 SAQs (25 Marks)
Credit 01 to 02 : 01 LAQ out of 02 LAQs (10 Marks)
Credit 03 to 04 : 01 LAQ out of 02 LAQs (10 Marks)
Credit 01 to 04 : 01 LAQ out of 02 LAQs (10 Marks)
LAQ may contains sub-questions</td><td>70 Marks</td></tr>
</table></td></tr>
<tr><td>2</td><td>Theory (T)

2 Credit
50 Marks

CA: 30%
EE: 70%</td><td colspan="2">Each student is required to attempt total 01 (One) “Continuous Assessment (CA)” for each course of each Semester, as per the following details:
1. CA01: 1 (One) ‘Continuous Assessment 01 (CA01)’ on Credit 01 and Credit 02 of each course, consists of
• 1 (One) ‘Short Answer Question (SAQ)’ of 5 Marks
and
• 1 (One) ‘Long Answer Question (LAQ)’of 10 Marks, LAQ may consist of sub-questions.
CA01: On Credit 01 and Credit 02, of Marks = (5 + 10) = 15 Marks
2. Maximum number of attempts for CA, during each semester: Single attempt only
3. Total Marks: 15 Marks</td><td colspan="2">1. Student is required to answer 05 ‘VSAQs’ out of 06 ‘VSAQs’, each carrying 03 Marks, on Credit 01 to 02, for total 15 Marks. One VSAQ will be on each Credit.
2. Student is required to answer 02 ‘SAQs’ out of 03 ‘SAQs’, each carrying 05 Marks, on Credit 01 to 02, for total 10 Marks. One SAQ will be on each Credit.
3. Student is required to answer 01 ‘LAQ’ out of 2 LAQs, of 10 Marks on Credit 01 and Credit 02, for total 10 Marks. LAQ may consist of sub-questions.
4. Number of attempts: Till Valid Registration Period (VRP) only
5. Marks: 35 Marks
6. Duration: 75 minutes</td></tr>
</table>

<table>
<tr><th>SN</th><th>Type of Course</th><th colspan="2">Continuous Assessment (CA)</th><th colspan="2">End Examination (EE)</th></tr>
<tr><td></td><td></td><td colspan="4"><table>
<tr><td>SN</td><td>Description</td><td colspan="2">Evaluation of End Examination (EE)</td><td>Marks</td></tr>
<tr><td rowspan="3">1</td><td rowspan="3">Question Types</td><td colspan="2">Very Short Answer Question (VSAQ) on each Credit</td><td>03 Marks</td></tr>
<tr><td colspan="2">Short Answer Question (SAQ) on each Credit</td><td>05 Marks</td></tr>
<tr><td colspan="2">On each Credit, either Single Long Answer Question (LAQ) or LAQ contains sub-questions (a), (b) and so on.</td><td>10 Marks</td></tr>
<tr><td>2</td><td>Grand Total Marks</td><td colspan="2">Total three Questions in EE Question paper based on:
Credit 01 to 02 : 05 VSAQs out of 06 VSAQs (15 Marks)
Credit 01 to 02 : 02 SAQs out of 03 SAQs (10 Marks)
Credit 01 to 02 : 01 LAQ out of 02 LAQs (10 Marks)
LAQ may contains sub-questions</td><td>35 Marks</td></tr>
</table></td></tr>
</table>

<table>
<tr><th>SN</th><th>Type of Course</th><th colspan="4">Continuous Assessment (CA)</th><th>End Examination (EE)</th></tr>
<tr><td>3</td><td>Practical (P)

4 Credit
100 Marks

CA: 50%
EE: 50%</td><td colspan="4">1. Student is required to submit “Activity Report in Work-Book Format” for each Credit in the prescribed format.
2. Maximum number of attempts for each CA, during each semester : Single attempt only
3. Marks: 50 Marks
4. Grading criteria:
<table><tr><td>Lab Punctuality, Preparedness & Ethics</td><td>Irregular in lab. Copies the experiment from others
(0 Points)</td><td>Consistently regular but unable to explain the concepts
(06 Points)</td><td>Punctuality in lab. Follows the procedure and responds to questions asked
(10 Points)</td></tr><tr><td>Activity Report and Performance

(Experiment No, Date, Objectives, Apparatus with specification, Observations, Graphs, software used if any)</td><td>Poor Documentation and copied the experiment from others.
Couldn't perform the Activity /poor observation made
(04 Points)</td><td>Average Documentation : Report is in format but some of the formatting guidelines are missed.
Performed the Activity but observations made with some mistakes
(12 Points)</td><td>Good Documentation: Lab activity writing is in proper format with all references, Grammar.
Performed the Activity on time observations made with no mistakes
(20 Points)</td></tr><tr><td>Results and Conclusion</td><td>Unable to achieve the desired results but makes attempts to relate data to theory. Poor concluding statements
(08 Points)</td><td>Average graphical and tabulated representation with misinterpret physical significance of theory. Achieve the desired results and but insufficient conclusion statement.
(14 Points)</td><td>Analyses and interpret observed data carefully with good graphical and tabulated representation using appropriate theory/evidence. Achieve the results and reach to appropriate Conclusion
(20 Points)</td></tr></table></td><td>External and internal examiners shall assess each student based on:
1. Workbook/Activity Report submission by the student (Only by External Examiner) [05 Marks]
2. Practical Activity performed by the student [12 Marks]
3. Result and Conclusion of the Practical Activity [13 Marks]
4. Viva-Voce on Practical Activities [20 Marks]
5. Number of attempts: Till Valid Registration Period (VRP) only
6. Marks: 50 Marks
7. Duration: 180 minutes</td></tr>
</table>

<table>
<tr><th>SN</th><th>Type of Course</th><th colspan="2">Continuous Assessment (CA)</th><th>End Examination (EE)</th></tr>
<tr><td></td><td></td><td colspan="3"><table>
<tr><td rowspan="2">SN</td><td colspan="3">Evaluation of Practical End Examination</td></tr>
<tr><td>Description</td><td>Internal Examiner</td><td>External Examiner</td></tr>
<tr><td>1</td><td>Workbook/Activity Report</td><td>-</td><td>05 Marks</td></tr>
<tr><td>2</td><td>Actual Conduct of one randomly selected Practical Activity</td><td>02 Marks</td><td>10 Marks</td></tr>
<tr><td>3</td><td>Diagram, Synoptic Answers, Graph/Observation and Conclusion</td><td>03 Marks</td><td>10 Marks</td></tr>
<tr><td>4</td><td>Viva-Voce/Oral</td><td>05 Marks</td><td>15 Marks</td></tr>
<tr><td>5</td><td>Total</td><td>10 Marks</td><td>40 Marks</td></tr>
</table></td></tr>
</table>

<table>
<tr><th>SN</th><th>Type of Course</th><th>Continuous Assessment (CA)</th><th>End Examination (EE)</th></tr>
<tr><td>4</td><td>Field Project (TW)

4 Credit
100 Marks

CA: 50%
EE: 50%</td><td>Students need to complete one month Field Project (Total Study hours 120 hrs including Activity Report). After completion of the field project, learners shall submit a report to the LSC - Programme Coordinator (PC) and Mentor/Guide.
1. Maximum number of attempts for each CA, during each semester: Single attempt only
2. Duration: 1 Month or 4 Weeks duration –i) After end examination of semester 02 and before beginning of semester 03 or
ii) Any one month during semester 02 duration
3. Marks: 50 Marks
4. Grading Criteria for Evaluation of FP (only by Mentor/Guide):
<table><tr><th>SN</th><th>Description</th><th>Marks</th></tr><tr><td>1</td><td>Key Definitions of Problem area and analysis of preliminary data</td><td>15</td></tr><tr><td>2</td><td>Work related to formats, Correspondence, Interactions and liaising etc</td><td>05</td></tr><tr><td>3</td><td>Field work and data collection</td><td>15</td></tr><tr><td>4</td><td>Analysis and Report</td><td>10</td></tr><tr><td>5</td><td>Feedback to community</td><td>05</td></tr><tr><td colspan="2">Total</td><td>50</td></tr></table></td><td>1. External and Internal examiners (Internal examiner - Programme Coordinator (PC) / Supervisor of LSC) shall assess each student based on:
a. Activity Report submission by the student (Only by External Examiner) [10 Marks]
b. Viva-Voce on Activity Report [40 Marks]
2. Number of attempts: Till Valid Registration Period (VRP) only
3. Marks: 50 Marks
4. Duration: 180 minutes</td></tr>
<tr><td colspan="4"><table><tr><th rowspan="2">SN</th><th colspan="3">Evaluation of Field Project End Examination</th></tr><tr><th>Description</th><th>Internal Examiner (Programme Coordinator (PC)/ Supervisor of LSC)</th><th>External Examiner</th></tr><tr><td>1</td><td>Workbook/Report submission</td><td>-</td><td>10 Marks</td></tr><tr><td>2</td><td>Viva-Voce /Oral</td><td>10 Marks</td><td>30 Marks</td></tr><tr><td>3</td><td>Total</td><td>10 Marks</td><td>40 Marks</td></tr></table></td></tr>
</table>

<table>
<tr><th>SN</th><th>Type of Course</th><th>Continuous Assessment (CA)</th><th>End Examination (EE)</th></tr>
<tr><td>5</td><td>OJT or Internship (TW)

4 Credit
100 Marks

CA: 50%
EE: 50%</td><td>
1. Students need to complete one month On Job Training (OJT) or Internship (Total Study hours 120 hrs including Internship Report) in any Industry/Organization/Institute/ R&D Division /Any Micro/Small/Medium/enterprise/Govt /NGO/PSU/Online Internship related to major course.
2. Maximum number of attempts for each CA, during each semester: Single attempt only
3. Marks: 50 Marks
4. Duration: 1 Month or 4 Weeks –
i) After end examination of semester 02 and before beginning of semester 03.
or
ii) Any one month during semester 02 duration
5. Grading Criteria for Evaluation of OJT (or Intern) only by Mentor where the Internship is proposed to be imparted:
<table>
<tr><th>SN</th><th>Parameters</th><th>Marks Out of</th></tr>
<tr><td>1</td><td>Behaviors, Shows interest in assigned work, Willingness to learn</td><td>10</td></tr>
<tr><td>2</td><td>Accepts responsibility, Cooperates with co-workers and supervisors, Demonstrates organizational skills</td><td>10</td></tr>
<tr><td>3</td><td>Uses time, knowledge and expertise effectively, Analyzes problems effectively</td><td>10</td></tr>
<tr><td>4</td><td>Demonstrates creativity/ originality / any innovative contribution, Professional ethics and accountability</td><td>10</td></tr>
<tr><td>5</td><td>Writes effectively, Produces high quality work/Skill Proficiency</td><td>10</td></tr>
<tr><td colspan="2">Total</td><td>50</td></tr>
</table>
Document as Evidence: Activity report along with Certificate or Declaration, duly issued and signed by the concerned authority [To be assessed during EE] should be submitted during End Examination to the parent Learner support Centre (LSC).
</td><td>
At the end of second semester, Programme Coordinator (PC)/ Supervisor of LSC and 1 (one)External Examiner will complete ‘End Exam (EE)’ for all allotted students as follows:
1. Duration of EE: After Theory EE of second Semester
2. Programme Coordinator (PC)/ Supervisor of LSC and External Expert will have 20% and 80% weightage respectively in EE.
3. Number of attempts: Till Valid Registration Period (VRP) only
4. Marks for EE: 50 Marks
<table>
<tr><th>Parameter</th><th>PC /Supervisor of LSC</th><th>External Expert</th></tr>
<tr><td>Professional Attitude</td><td>-</td><td>05 Marks</td></tr>
<tr><td>Maintenance of Daily Diary</td><td>-</td><td>10 Marks</td></tr>
<tr><td>Internship Report</td><td>05 Marks</td><td>10 Marks</td></tr>
<tr><td>Viva/Oral</td><td>05 Marks</td><td>15 Marks</td></tr>
<tr><td>Total</td><td>10 Marks</td><td>40 Marks</td></tr>
</table>
</td></tr>
</table>

<table>
<tr><th>SN</th><th>Type of Course</th><th>Continuous Assessment (CA)</th><th>End Examination (EE)</th></tr>
<tr><td>6</td><td>Project Work (PW)

RP-I
4 Credit
100 Marks

CA: 50%
EE: 50%</td><td>1. Student is required to submit “Activity Report” based on Grading Criteria of the course in the prescribed format.
2. Maximum number of attempts for each CA, during each semester: Single attempt only
3. Marks: 50Marks
4. Grading Criteria:
<table>
<tr><th>SN</th><th>Desc</th><th>Marks</th></tr>
<tr><td>1</td><td>Seminar*</td><td>25</td></tr>
<tr><td>2</td><td>Research Proposal</td><td>25</td></tr>
</table>
*To be conducted in Online/Offline mode at LSC.</td><td>1. External and internal examiners shall assess each student based on:
a. Project Report submission by the student (Only by External Examiner) [10 Marks]
b. Project Presentation by the student [20 Marks]
c. Viva-Voce on Project Report [20 Marks]
2. Number of attempts: Till Valid Registration Period (VRP) only
3. Marks: 50 Marks
4. Duration: 180 minutes</td></tr>
<tr><td colspan="4">
<table>
<tr><th rowspan="2">SN</th><th colspan="3">Evaluation of Project Work End Examination</th></tr>
<tr><th>Description</th><th>Internal Examiner</th><th>External Examiner</th></tr>
<tr><td>1</td><td>Project Report</td><td>-</td><td>10 Marks</td></tr>
<tr><td>2</td><td>Project Presentation</td><td>05 Marks</td><td>15 Marks</td></tr>
<tr><td>3</td><td>Viva-Voce /Oral</td><td>05 Marks</td><td>15 Marks</td></tr>
<tr><td>4</td><td>Total</td><td>10 Marks</td><td>40 Marks</td></tr>
</table>
</td></tr>
</table>

<table>
<tr><th>SN</th><th>Type of Course</th><th>Continuous Assessment (CA)</th><th>End Examination (EE)</th></tr>
<tr><td>7</td><td>Project Work (PW)

RP-II

6 Credit
150 Marks

CA: 50%
EE: 50%</td><td>1. Student is required to submit “Activity Report” based on Grading Criteria of the course in the prescribed format.
2. Maximum number of attempts for each CA, during each semester: Single attempt only
3. Marks: 75 Marks
4. Grading Criteria:
<table>
<tr><td>SN</td><td>Desc</td><td>Marks</td></tr>
<tr><td>1</td><td>Seminar*</td><td>30</td></tr>
<tr><td>2</td><td>Research Paper Presentation**</td><td>30</td></tr>
<tr><td>3</td><td>Project Report</td><td>15</td></tr>
</table>
*To be conducted in Online/Off line mode at LSC.
** Journals/Conferences/ at LSC, in Online/Offline mode [This activity shall be organized by respective LSC in Online/Offline mode in case student didn’t get an opportunity for presentation at Journals/Conferences]</td><td>1. External and internal examiners shall assess each student based on:
a. Project Report submission by the student (Only by External Examiner) [20 Marks]
b. Project Presentation by the student [25 Marks]
c. Viva-Voce on Project Report [30 Marks]
2. Number of attempts: Till Valid Registration Period (VRP) only
3. Marks: 75 Marks
4. Duration: 180 minutes</td></tr>
<tr><td colspan="4">
<table>
<tr><td rowspan="2">SN</td><td colspan="3">Evaluation of Project Work End Examination</td></tr>
<tr><td>Description</td><td>Internal Examiner</td><td>External Examiner</td></tr>
<tr><td>1</td><td>Project Report</td><td>-</td><td>20 Marks</td></tr>
<tr><td>2</td><td>Project Presentation</td><td>05 Marks</td><td>20 Marks</td></tr>
<tr><td>3</td><td>Viva-Voce /Oral</td><td>10 Marks</td><td>20 Marks</td></tr>
<tr><td></td><td>Total</td><td>15 Marks</td><td>60 Marks</td></tr>
</table>
</td></tr>
</table>

1. **Separate and independent passing @ 40% in CA, EE and (CA+EE) shall be essential for each course - Theory, Practical, OJT/FP and RP.** “CA, EE and Total marks” shall be separately reported for each course in the transcript or mark-statement. The minimum and maximum marks for “CA, EE and Total Marks” are shown in the table below. If student does not score a minimum of 40% marks in CA or in EE of a course then the result of such a course will be reported as FAIL.

Course Type	Number of Credits	Continuous Assessment (CA)		End Examination(EE)		Total Marks ‘TM’ = (CA +EE)	
		Min	Max	Min	Max	Min	Max
Theory	2	6	15	14	35	20	50
	4	12	30	28	70	40	100
Practical/ OJT/FP/RP	4	20	50	20	50	40	100
	6	30	75	30	75	60	150

2. In each semester, only 1 attempt, for CA for each course and for EE for each course shall be allowed. Only during valid registration period (VRP), students are allowed to appear for CA and EE for each course against the payment of the specified 'Examination Fee' for each attempt, for each course where he/she is admitted by the university. The 'CA and/or EE' attempts are counted for each examination option offered by the university to the student, irrespective of whether student actually chooses to appear in end exam or not.

3. If a student does not successfully complete the continuous assessment (CA) or pass the End Examination of Practical/Term work/OJT/Field Project/Research Project courses, they may complete these requirements with the next semester at the respective Learning Support Center (LSC) only during the valid registration period (VRP).

4. Duration for Practical/Term work/OJT/Field Project/Research Project type of Courses: 180 Minutes for a batch of typically 15 ± 3 students

5. Only best of past performance shall be reported in transcript or mark statement.

6. **Total student evaluation for**

    a. **Each** semester shall be for **550** marks
    b. **Each** year shall be for **1100** marks
    c. **Each** regular PG degree shall be for **2200** marks

7. **Reporting Semesters** for certification:

    - Min 40% or better marks in total 23 courses (subjects) of total 88 credit points at Semesters 01-04.

SUCCESSFUL COMPLETION OF COURSE OR PROGRAMME

1. "Successful Completion of the Course" means - either course is exempted or student gets minimum specified or better grade, either in end examination of that course or by credit transfer. A student obtaining grade "F" shall be considered failed and will be required to reappear in the examination. The student obtained minimum "P" (Pass) letter grade required for successful completion of each course.
2. "Successful Completion of the Programme" means – all courses at all semesters are successfully completed and the student obtained "P" (Pass) letter grade for all courses at all semesters along with minimum specified SGPA and CGPA.

SEMESTER 01

MAT501: REAL ANALYSIS

PROGRAMME INFORMATION

SN	Description	Details
1	University	Yashwantrao Chavan Maharashtra Open University Nashik - 422 222, Maharashtra, India Website: http://www.ycmou.ac.in/and http://ycmou.digitaluniversity.ac/
2	School	School of Sciences
3	Discipline	Science
4	Level	PG
5	Course Used in	V151: M.Sc.(Mathematics) {2023 Pattern} & V130 M.Sc.(Mathematics){2021 Pattern}

COURSE INFORMATION

Sem	Major	Code	Course Name	CR	CST	ST	CA	EE	TM	Type
01	DSC	MAT501	Real Analysis	4	12	120	30	70	100	T

PRESUMED KNOWLEDGE AND LEARNING OBJECTIVES

Presumed Knowledge	Learning Objectives
For successful completion of this course, student should have successfully complete: • BSc/BA with Mathematics or equivalent from a recognized University/Board.	The objectives of this course are • To study Properties of Metric Spaces • To Understand concept of Riemann Integrability & its Properties • To study Convergence of Sequence of Functions & Power Series

UNITS

UN	Name of the Unit	CSs	Questions
01-01 01-02 01-03 01-04	**Metric Spaces** **Open and Closed Sets** **Sequences in Metric Spaces** **Continuity**	**CR 01**	As per evaluation pattern, on Each Credit, Student is required to answer • Very Short Answer Question (VSAQ), of 03 marks • Short Answer Question (SAQ), of 05 marks • Long Answer Question (LAQ) of 10 Marks (LAQ may contain sub-questions (a), (b) and so on.)
02-01 02-02 02-03 02-04	**Connected Metric Spaces** **Complete Metric Spaces** **Totally Bounded Subsets of Metric Spaces** **Compact Metric Spaces**	**CR 02**	
03-01 03-02 03-03 03-04	**Riemann Integral** **Necessary and Sufficient Conditions for Riemann Inegrability** **Properties of Riemann Integrals** **Mean Value Theorems and Fundamental Theorems of Calculus**	**CR 03**	

04-01 04-02 04-03 04-04	**Convergence and Uniform Convergence of Sequence of Functions** **Properties of functions preserved under uniform convergence** **Convergence and Uniform Convergence of Series of Functions** **Power series**	**CR 04**	

DETAILED SYLLABUS

UN	Detailed Syllabus of the Unit	CR
1-1	**Metric Spaces**: Definition and examples of Metric spaces, Standard Metrics on $\mathbb{R}^n$,Discrete Metric Spaces, Open and Closed Balls	**CR 01**
1-2	**Open and Closed Sets**: Definition and examples of open and closed sets, unions and intersections open and closed sets, structure of open sets in $\mathbb{R}$, open and closed sets in subspaces.	
1-3	**Sequences in Metric Spaces:** Sequence and subsequence in Metric spaces, Convergence of sequence in metric spaces, Algebra of convergent sequences, Cauchy sequences and Bounded Sequences	
1-4	**Continuity**: Sequential Definition of continuity, Theorems of connected sets. Continuity in terms of open and closed sets, homeomorphism between two metric spaces, uniform continuity, examples.	
2-1	**Connected Metric Spaces**: Definition and examples of connected sets, equivalent characterization of connected sets, Connected subsets of $\mathbb{R}$, properties of continuous functions defined on connected metric spaces.	**CR 02**
2-2	**Complete Metric Spaces**: Definition and examples of complete sets, characterization of complete sets using limit point, relation between closed and complete spaces, and theorems on complete sets.	
2-3	**Totally Bounded Subsets of Metric Spaces**: Definition and examples of connected sets, equivalent definitions of totally bounded sets, relation between bounded and totally bounded sets, totally bounded subsets of $\mathbb{R}$.	
2-4	**Compact Metric Spaces** Definition and examples of compact sets, equivalent characterization of compact sets, theorems on compact sets, properties of continuous functions defined on compact metric spaces.	
3-1	**Riemann Integral:** Concept of Lebesgue measure sets of measure zero, lower and upper sum, defining Riemann Integral using upper and lower sums, numerical examples.	**CR 03**
3-2	**Necessary and Sufficient Conditions for Riemann Inegrability**: Various theorems on Necessary and Sufficient Conditions for Riemann Inerrability, examples of Riemann and non-Riemann integrable functions.	
3-3	**Properties of Riemann Integrals**: Algebra of Riemann integrable functions: addition, subtraction, scalar multiplication, absolute value etc., Inequalities on Riemann Integrals, Riemann integrals of non –negative functions, examples.	
3-4	**Mean Value Theorems and Fundamental Theorems of Calculus:** Definition of derivative of real valued functions of real variable, Rolle's theorem, Lagrange's Mean Value Theorem, Cauchy's Mean Value Theorem, First and Second Fundamental Theorems of Calculus	
4-1	**Convergence and Uniform Convergence of Sequence of Functions:** Pointwise convergence of sequence of functions, Uniform convergence of sequence	**CR**

	of functions, Difference between pointwise and uniform convergence, examples.	04
4-2	**Properties of functions preserved under uniform convergence:** Theorems on Continuity, Integrability and Differentiability of sequence of functions under uniform convergence, examples.	
4-3	**Convergence and Uniform Convergence of Series of Functions:** Pointwise convergence of series of functions, Uniform convergence of sequence of functions, Properties of functions preserved under uniform convergence of series of functions, Weierstrass M-Test for Uniform Convergence of series of functions, examples.	
4-4	**Power series**: Conditions for uniform convergence of power series, term by term differentiation and integration of power series, examples.	

LEARNING RESOURCE DETAILS

LR Code	Title Author	Edition Year	ISBN Publisher
Course Website Link for (1) Mobile and Online Lectures, (2) Discussion Forum for online interaction and (3) Self-Test for each CR Block, Continuous Assessment Test and End Examination			
CW-MAT501			
Text-Books			
MAT501-T01	Real Analysis, Dr. Subhash G. Pawar & Mr. Chetan Shirore	2021	978-93-91514-46-4 YCMOU
Reference-Books: Explore additional details and reinforce learning, with this optional learning resource!			
MAT501 – RB1	Methods of Real Analysis, Richard R. Goldberg	2nded Reprint 2017	9788120417571 Oxford & IBH Publishing Co. Pvt Ltd
MAT501 – RB2	Principles of Mathematical Analysis, Rudin Walter	3rd, 1976,	McGraw Hill Inc.,USA
MAT501 – RB3	Introduction to Real Analysis, Bartle Robert G and Sherbert Donald R	2010	Wiley India Edition,
MAT501 – RB4	Lectures on Advanced Real Analysis, KaradeT .M. and Salunke J N	2004	SonuNilu
MAT501 – RB5	Real Analysis, Royden H L	4th, 1993	Macmillan Co Inc, New York,
MAT501 – RB6	Topology of Metric Spaces, S Kumaresan	2nd 2011	9788184870589 Narosa Publishing House
MAT501 – RB7	Real Analysis, N.L. Carothers	1st Edition	Cambridge University Press.
CD / DVD: Explore additional details and reinforce learning, with this optional learning resource!			
MAT501 - CD1			
Web Links: Explore additional details and reinforce learning, with this optional learning resource!			
MAT501-WL1			

COURSE OUTCOMES

After successful completion of this course, student should be able to

- Comprehend the aspect of Metric Space which forms foundation for topology
- Understand thorough foundation of Riemann integration theory
- Use convergence of sequence and series of functions to evaluate Riemann integration of functions

MAT502: ABSTRACT ALGEBRA

PROGRAMME INFORMATION

SN	Description	Details
1	University	Yashwantrao Chavan Maharashtra Open University Nashik - 422 222, Maharashtra, India Website: http://www.ycmou.ac.in/and http://ycmou.digitaluniversity.ac/
2	School	School of Sciences
3	Discipline	Science
4	Level	PG
5	Course Used in	V151: M.Sc.(Mathematics) {2023 Pattern} & V130 M.Sc.(Mathematics){2021 Pattern}

COURSE INFORMATION

Sem	Major	Code	Course Name	CR	CST	ST	CA	EE	TM	Type
01	DSC	MAT502	Abstract Algebra	4	12	120	30	70	100	T

PRESUMED KNOWLEDGE AND LEARNING OBJECTIVES

Presumed Knowledge	Learning Objectives
For successful completion of this course, student should have successfully complete: • BSc/BA with Mathematics or equivalent from a recognized University/Board.	The objectives of this course are • To understand basic concepts of direct product of groups, Series of Groups, Prime & Maximal Ideals • To Study Solvable Groups, Sylow Theorem • To discuss polynomial rings their roots and factorizations. • To demonstrate Euclidean domains, principal ideal domains and unique factorization domains.

UNITS

UN	Name of the Unit	CSs	Questions
01-01 01-02 01-03 01-04	**Direct product of groups** **Finitely generated abelian groups** **Normal Subgroups** **Homomorphisms of groups**	**CR 01**	As per evaluation pattern, on Each Credit, Student is required to answer • Very Short Answer Question (VSAQ), of 03 marks • Short Answer Question (SAQ), of 05 marks • Long Answer Question (LAQ) of 10 Marks (LAQ may contain sub-questions (a), (b) and so on.)
02-01 02-02 02-03 02-04	**Series of Groups** **Solvable groups** **Group action on a set** **Sylow Theory**	**CR 02**	
03-01 03-02 03-03 03-04	**Maximal and Prime ideals** **Ring of Polynomials** **Factorization of a polynomials over a field** **Factorization over Domains**	**CR 03**	
04-01 04-02 04-03 04-04	**Euclidean Domains** **Principal ideal domains** **Unique factorization Domains** **Ring of Gaussian Integers**	**CR 04**	

DETAILED SYLLABUS

UN	Detailed Syllabus of the Unit	CR
1-1	**Direct product of groups:** (Preliminaries on groups, subgroups and cyclic groups) External direct product, Internal direct product and join of subgroups.	CR 01
1-2	**Finitely generated Abeliangroups:** Generators and torsion group, finitely generated groups, Fundamental theorem for finitely greeted Abeliangroups, Applications of fundamental theorem, decomposition of groups.	
1-3	**Normal Subgroups:** Cosets, inner Automorphisms and normal groups, factor groups, Simple groups, Commutator subgroup.	
1-4	**Homomorphism of groups:** Isomorphism theorems, Maximal normal subgroups,Zassenhaus Lemma.	
2-1	**Series of Groups:** Subnormal and normal series of groups, composition series, Jordan-Holder theorem.	CR 02
2-2	**Solvable groups**: Solvable groups, Nilpotent groups, interrelation.	
2-3	**Group action on a set**: G-set, isometry subgroup, orbits, Applications of action of a group.	
2-4	**Sylow Theory:** Burnside theorem, p-groups, Cauchy's theorem, Sylow's theorems, Class Equation, Conjugate class, Application of Sylow's theorems to simple and abelian groups.	
3-1	**Maximal and Prime ideals:**(Preliminaries of rings, ideals and homomorphism) Fundamental theorem of ring homomorphisms, Maximal and Prime ideals, Prime fields.	CR 03
3-2	**Ring of Polynomials**: Polynomial in indeterminate, The Evaluation homomorphisms, Zeros of a polynomial.	
3-3	**Factorization of a polynomials over a field**: The division algorithm, irreducible polynomials, Eisenstein criterion, Unique factorization in $F[x]$.	
3-4	**Factorization over Domains**: Divisibility, Associates, units, irreducible elements, prime elements, ideals generated by prime element.	
4-1	**Euclidean Domains:** Euclidean valuation, Euclidean domain, Arithmetic's in Euclidean domain, Euclidean algorithm, Gaussian integers, multiplicative norms.	
4-2	**Principal ideal domains:** Principal ideal domain, Ascending chain conditions over PID, Prime elements and fundamental theorem of arithmetic's, primitive polynomials, Gauss lemma.	
4-3	**Unique Factorization Domains:** Factorization Domain, Unique factorization domain.	
4-4	**Ring of Gaussian Integers:** Euclidean algorithm, Gaussian integers, multiplicative norms.	

LEARNING RESOURCE DETAILS

LR Code	Title Author	Edition Year	ISBN Publisher
Course Website Link for (1) Mobile and Online Lectures, (2) Discussion Forum for online interaction and (3) Self-Test for each CR Block, Continuous Assessment Test and End Examination			
CW-MAT502			
Text-Books			

MAT502-T01	Abstract Algebra, Dr. S.R. Chaudhari&Dr. J. N. Chaudhari	2020	978-93-91514-47-1 YCMOU
Reference-Books: Explore additional details and reinforce learning, with this optional learning resource!			
MAT502 – RB1	A First Course in Abstract Algebra, J.B. Fraleigh	3rd 2002	Narosa Publishing House New Delhi.
MAT502 – RB2	Topics in Algebra, Herstein I N	1975	Wiley Eastern Ltd. New Delhi,
MAT502 – RB3	Basic Abstract Algebra, Bhattacharya P B, Jain S K and Nagpaul S.R.	2nd 1995	
MAT502 – RB4	Abstract Algebra, Dummit David S and Foote Richard M	3rd	Wiley India Edition
MAT502 – RB5	Contemporary Abstract Algebra, J.A. Gallian,		Narosa Publication
CD / DVD: Explore additional details and reinforce learning, with this optional learning resource!			
MAT502 - CD1			
Web Links: Explore additional details and reinforce learning, with this optional learning resource!			
MAT502-WL1			

COURSE OUTCOMES

After successful completion of this course, student should be able to

- Build foundation of group and ring theory
- Apply the concept of subgroup and normal subgroups to discuss the solvability of groups and thereby solvability of equations of any positive order
- Generalize the concepts of divisibility to rings and apply them in general context and factorize polynomials.

MAT503: Ordinary Differential Equations

Programme Information

SN	Description	Details
1	University	Yashwantrao Chavan Maharashtra Open University Nashik - 422 222, Maharashtra, India Website: http://www.ycmou.ac.in/and http://ycmou.digitaluniversity.ac/
2	School	School of Sciences
3	Discipline	Science
4	Level	PG
5	Course Used in	V151: M.Sc.(Mathematics) {2023 Pattern} & V130 M.Sc.(Mathematics){2021 Pattern}

Course Information

Sem	Major	Code	Course Name	CR	CST	ST	CA	EE	TM	Type
01	DSC	MAT503	Ordinary Differential Equations	2	6	60	15	35	50	T

Presumed Knowledge and Learning Objectives

Presumed Knowledge	Learning Objectives
For successful completion of this course, student should have successfully complete: • BSc/BA with Mathematics or equivalent from a recognized University/Board.	The objectives of this course are • Explain the basic notions in differential equations and use the results in developing advanced mathematics. • To discuss Dependence and Independence of solutions • To study non-homogeneous differential equation of higher order

Units

UN	Name of the Unit	CSs	Questions
01-01 01-02 01-03 01-04	**Linear Equations with constant coefficients** **Dependence and independence of solutions** **Applications of Second Order Linear Equations** **The homogeneous equation of higher order**:	**CR 01**	As per evaluation pattern, on Each Credit, Student is required to answer • Very Short Answer Question (VSAQ), of 03 marks • Short Answer Question (SAQ), of 05 marks • Long Answer Question (LAQ) of 10 Marks (LAQ may contain sub-questions (a), (b) and so on.)
02-01 02-02 02-03 02-04	**The non-homogeneous equation of higher order** **Linear Equations with variable Coefficients** **Reduction of the order** **Homogeneous equations with analytic coefficients**	**CR 02**	

Detailed Syllabus

UN	Detailed Syllabus of the Unit	CR
1-1	**Linear Equations with Constant Coefficients:** Introduction, The second order homogeneous equation Initial value problems for second order equations, Uniqueness theorem	**CR 01**
1-2	**Dependence and independence of solutions:** Linear dependence and	

	independence, A formula for the Wronskian, The non-homogeneous equation of order two.	
1-3	**Applications of Second Order Linear Equations:** Hooke's Law, Force acting upon the mass, Free, damped and undamped motion and Electric circuit problems	
1-4	**The homogeneous equation of higher order**: Initial value problems for n^{th} order equations, Existence and uniqueness theorems, Equations with real constants	
2-1	**The non-homogeneous equation of higher order:** A special method for solving the non-homogeneous equation, Algebra of constant coefficient operators.	**CR 02**
2-2	**Linear Equations with Variable Coefficients:** Introduction, Initial value problems for the homogeneous equation, Existence and uniqueness theorems, Solutions of the homogeneous equation.	
2-3	**Reduction of the order:** The Wronskian and linear independence, Reduction of the order of a homogeneous equation, The non-homogeneous equation.	
2-4	**Homogeneous equations with analytic coefficients**: Existence theorem for homogeneous equations with analytic coefficients, The Legendre equation, Power series method and problems.	

LEARNING RESOURCE DETAILS

LR Code	Title Author	Edition Year	ISBN Publisher
Course Website Link for (1) Mobile and Online Lectures, (2) Discussion Forum for online interaction and (3) Self-Test for each CR Block, Continuous Assessment Test and End Examination			
CW-MAT503			
Text-Books			
MAT503-T01	Ordinary Differential Equations, Dr. H.L. Tidke &Dr. L. N. Katkar	2021	978-93-91514-52-5 YCMOU
Reference-Books: Explore additional details and reinforce learning, with this optional learning resource!			
MAT503 – RB1	An Introduction to Ordinary Differential Equations, Earl A. Coddington	2009	PHI Learning Private Limited, New Delhi
MAT503 – RB2	Differential equations, Ross Shepley L. (for UN: 1-3)	3rd, 2007	Wiley – India,
MAT503 – RB3	Ordinary differential equations, Birkhoff Garrett and Rota Gian - Carlo	3rd, 1978	John Wiley and Sons, Third edition,
MAT503 – RB4	Lectures on ordinary differential equations, Karade T M	1995	Unpublished,
CD / DVD: Explore additional details and reinforce learning, with this optional learning resource!			
MAT503 - CD1			
Web Links: Explore additional details and reinforce learning, with this optional learning resource!			
MAT503-WL1			

COURSE OUTCOMES

After successful completion of this course, student will be able to

- Understand various methods of solutions of differential equations of first and second order.
- Apply these methods to solve differential equations in physics and engineering fields
- Discuss approximation and existence & uniqueness of solution of nth order differential equations to solve them using the techniques discussed thereby.

MAT504: Programming in C and Scilab

Programme Information

SN	Description	Details
1	University	Yashwantrao Chavan Maharashtra Open University Nashik - 422 222, Maharashtra, India Website: http://www.ycmou.ac.in/and http://ycmou.digitaluniversity.ac/
2	School	School of Sciences
3	Discipline	Science
4	Level	PG
5	Course Used in	V151: M.Sc.(Mathematics) {2023 Pattern}

Course Information

Sem	Major	Code	Course Name	CR	CST	ST	CA	EE	TM	Type
01	DSC	MAT504	Programming in C and Scilab	4	12	120	50	50	100	P

Presumed Knowledge and Learning Objectives

Presumed Knowledge	Learning Objectives
For successful completion of this course, student should have successfully complete: • BSc/BA with Mathematics or equivalent from a recognized University/Board.	The objectives of this course are • To learn how to write simple mathematical programs in C • To learn how to perform Matrix operations in C • To learn how to write program for Numerical Methods in C • To make the students experts in solving mathematical problems through Scilab programming • To represents solutions of various equations graphically which indicate nature of the problem as well as solutions

Note: (1) The theoretical background relevant to the experiments listed below should be discussed during practical sessions only.

(2) Wherever possible, the output should be presented in graphical form also.

Detailed Syllabus

SN.	Syllabus	CR
1	**Getting Started with C:** The C Character Set,Constants, Variables and Keyword, Types of C Constants, Rules for Constructing Integer Constants, Rules for Constructing Real Constants, Rules for Constructing Character Constants, Types of C Variables,Rules for Constructing Variable Names	CR 01 & CR 02
2	**The First C Program:** Form of a C Program, Comments in a C Program, What is main( )?, Variables and their Usage, printf( ) and its Purpose, Compilation and Execution, Receiving Input	
3	**Preparing, running a complete C Program and Control Statements:** Preliminaries, The while statement, The do-while statement, The for statement, Nested loops. The if-else statement	

4	**Preparing, running a complete C Program and Control Statements:** The switch statement, The break statement, The continue statement, The comma operator, The goto statement.	
5	**Functions and Arrays** Introduction to a function, Defining a function, Accessing a function, Passing arguments to a function. Function prototypes, Recursion	
6	**Arrays:** Defining an array, Processing an array, Passing arrays to functions, Multidimensional arrays, Arrays and strings	
7	**Simple C Programs: (Any One)** i)C Program to Check Whether a Given Number is Even or Odd ii)C Program to Find Sum of Digits of a Number	
8	**C Programs on Numbers**: **(Any One)** i)Checking and printing of prime numbers ii)C Program to Find Sum of Natural Numbers using Recursion	
9	**C Programming on Math Functions: (Any One)** i)C Program to Calculate the Value of sin(x), cos(x) ii)C Program to Find Quotient and Remainder iii) C Program to Find the Roots of a Quadratic Equation	
10	**C Programming on Progression Series: (Any One)** i) C program to Find the Sum of Arithmetic Progression Series ii)C program to Find the Sum of Geometric Progression Series iii)C program to Find the Sum of Harmonic Progression Series	
11	Sorting of (1) Numerical data (2) Character type data- ascending, descending.	
12	**C Programs on Matrix operations : (Any Two)** i) C Program to Perform Matrix Addition, Multiplication ii) C Program to Display Upper Triangular Matrix iii) C Program to Find Transpose of a Matrix iv) C Program to Find Determinant of a Matrix v) C Program to Find Trace of a Matrix vi) C Program to Find the inverse of a nxn matrix and display both matrices.	
13	**C Program on Root of equation**: i) Bisection method ii)Newton Raphson method	
14	**Introduction to Scilab:** Installation, Introduction to Console, Editor, Docking	**CR 03**
15	**Basic Elements of the Language:** Creating real variables, Variable Name, Comments and continuation lines,Elementary Mathematical Functions, Predefined Mathematical Variables, Booleans, Complex Numbers, Strings, Dynamic type Variables	
16	**Matrices:** Create a matrix of real values, Accessing the elements of a matrix, Thecolon ":" operator, The dollar "$" operator, Algebra of matrices: Addition, multiplication, transpose.	
17	**Common Functions for Linear Algebra:** Calculation of Determinant, Inverse, Trace, Eigen values and Eigen vectors of a matrix, etc	
18	**Looping and branching: The if statement,** The select statement, The for statement, The while statement, The break and continue statements	
19	**Plotting graphs of Functions:**Plotting of 2D Graphs, Titles, axis and legends, Export	

20	**Solution of System of Linear Equations:**Jacobi and Gauss-Seidel Method: Inverse Method, Backslash method, Jacobi and Gauss-Seidel	**CR 04**
21	**Creation of Script Files & Functions files:**Defining a function, Function libraries, Managing output arguments	
22	**Numerical Methods:** Finding Roots of Algebraic and Transcendental Equations Bisection Method, Newton-Raphson Method	
23	**Numerical Integration for Solving Definite Integrals:** The Trapezoidal Rule, Simpson's 1/3rd Rule, Simpson's 3/8th Rule	
24	**Numerical Solution** of Ordinary Differential Equations Using Runge-Kutta Method	

LIST OF PRACTICAL ACTIVITIES

SN.	Title of Practical Activity	CR
1	C Programme for Sum of Digits of an Integer	**CR 01**
2	C Programme for Factorial of a Number	
3	C Programme for Checking and Printing of Prime Numbers	
4	C Programme for Trigonometric Functions Sin(x) and Cos(x) Using Series Method	
5	C Programme for Sorting of (1) Numerical data (2) Character type data-ascending, descending	
6	C Programme for Use of Pointers for Sorting	
7	C Programme for Matrix Operation: Addition, Subtraction and Multiplication	**CR 02**
8	C Programme for Bisection Method	
9	C Programme for Newton-Raphson Method	
10	C Programme for Trapezoidal Rule& Simpson's 1/3rdRule	
11	C Programme for Legendre Polynomials	
12	C Programme for Lagrange Interpolation	
13	C Programme for Inverse of Matrix	
14	Introduction to Scilab	**CR 03**
15	Basic Elements of the Language Scilab	
16	Vector operations and Matrices in Scilab	
17	Matrix operations in Scilab	
18	Looping and branching in Scilab	
19	Plotting graphs of Functions in Scilab	
20	Solution of System of Linear Equations: Jacobi and Gauss-Seidel Method in Scilab	**CR 04**
21	Creation of Script Files & Functions files in Scilab	
22	Numerical Methods: Finding Roots of Algebraic and Transcendental Equations, Bisection Method, Newton-Raphson Method in Scilab	
23	Numerical Integration for Solving Definite Integrals in Scilab	
24	Numerical Solutionof Ordinary Differential Equations Using Euler Method or first order Runge-Kutta Method in Scilab	

LEARNING RESOURCE DETAILS

LR Code	Title Author	Edition Year	ISBN Publisher
Course Website Link for (1) Mobile and Online Lectures, (2) Discussion Forum for online interaction and (3) Self-Test for each CR Block, Continuous Assessment Test and End Examination			
CW-			
Text-Books			
MAT504-T01			
Reference-Books: Explore additional details and reinforce learning, with this optional learning resource!			
MAT504-R01	Let Us C, Yashavant Kanetkar		
MAT504-R02	The C Programming Language, Brian W. Kernighan, Dennis M. Ritchie, 2nd Edition		
MAT504-R03	Spirit of C: An Introduction to Modern Programming, Henry Mullish and Herbert L. Cooper,		Jaico Publishers
MAT504-R04	Programming with C, Byron S. Gottfried.		Schaum's Outline series
MAT504-R05	Introduction to Scilab, Michael Baudin	2010	Scilab Consortium
MAT504-R06	Scilab for very beginners, Scilab Enterprises and Christine Gomez	2013	Scilab Enterprises
MAT504-R06	Scilab A Hands on Introduction, Satish Annigeri Ph.D.	2009	
CD / DVD: Explore additional details and reinforce learning, with this optional learning resource!			
MAT504--CD1			
Web Links: Explore additional details and reinforce learning, with this optional learning resource!			
MAT504--WL1	https://www.scilab.org/download/scilab-2024.0.0		
MAT504—WL2	ScilabSpoken Tutorial - IITB https://spoken-tutorial.org/tutorial-search/?search_foss=Scilab&search_language=English		
MAT504—WL3	https://scilab.in/		

COURSE OUTCOMES

After successful completion of this course, student will be able to

- Use numerical methods in solving problems in Maths, Physics, Chemistry and any other areas using C.
- Perform various Matrix Operations using C.
- Write, compile and debug programs in Scilab.
- Understand and solve matrices operations effectively using Scilab
- Use conditional expressions and looping statement to solve problems associated with conditions and repetitions
- Solve problems by using various numerical methods in Scilab
- Plot the 2D graphs in Scilab

RES 505: RESEARCH METHODOLOGY

PROGRAMME INFORMATION

SN	Description	Details
1	University	Yashwantrao Chavan Maharashtra Open University Nashik - 422 222, Maharashtra, India Website: http://www.ycmou.ac.in/and http://ycmou.digitaluniversity.ac/
2	School	School of Sciences
3	Discipline	Science
4	Level	PG
5	Course Used in	V151: M.Sc.(Mathematics) {2023 Pattern}, V152: M.Sc.(Environmental Science) {2023 Pattern}, V153: M.Sc.(Physics) {2023 Pattern}, V154: M.Sc.(Chemistry) {2023 Pattern}, V155: M.Sc.(Zoolgy) {2023 Pattern}, V156: M.Sc.(Botany) {2023 Pattern},

COURSE INFORMATION

Sem	Other	Code	Course Name	CR	CST	ST	CA	EE	TM	Type
01	RM	RES505	Research Methodology	4	12	120	30	70	100	T

PRESUMED KNOWLEDGE AND LEARNING OBJECTIVES

Presumed Knowledge	Learning Objectives
For successful completion of this course, student should have successfully complete: • BSc/BA with Mathematics or equivalent from a recognized University/Board.	The objectives of this course are • To Introduce Research Methodology • To study data collection & representation methods • To demonstrate statistical tools for data analysis • To discuss Literature collection, Intellectual Property Rights, Research Databases and Metrics

UNITS

UN	Name of the Unit	CSs	Questions
01-01 01-02 01-03 01-04	**Research** **Methods in biological research** **Experimental design** **Sampling methods**	**CR 01**	As per evaluation pattern, on Each Credit, Student is required to answer • Very Short Answer Question (VSAQ), of 03 marks • Short Answer Question (SAQ), of 05 marks • Long Answer Question (LAQ) of 10 Marks (LAQ may contain sub-questions (a), (b) and so on.)
02-01 02-02 02-03 02-04	**Data collection** **Representation of data** **Graphical representation** **Analysis of data**	**CR 02**	
03-01 03-02 03-03 03-04	**Use of inferential statistical tools in research** **Biostatical Test** **Use of ANOVA** **Application of correlation of data**	**CR 03**	

04-01 04-02 04-03 04-04	**Literature collection** **Intellectual Property Rights** **Research Databases** **Research Metrics**	**CR 04**	

Important Note: This course is common across all Postgraduate Programmes in the 'School of Sciences', the content within the Research Methodology course should incorporate illustrations and examples relevant to their respective domains or disciplines.

DETAILED SYLLABUS

UN	Detailed Syllabus of the Unit	CR
1-1	**Research**: Basic and applied research, essential steps in research, Research – definition, importance and application.	CR 01
1-2	**Methods in biological research**: General methods in biological research – natural observation, field study, and experimentations.	
1-3	**Experimental design** – Basic principles, hypothesis, one & two group experimental design. Matched pair data analysis, factorial design, randomized block design.	
1-4	**Sampling methods** - Concept of population, random sampling and nonrandom sampling, variables – random, independent and intervening variables.	
2-1	**Data collections**: Methods for primary data- observation, interview, questionnaire methods, and experiments, Methods for secondary data – scientific journals, books, reports, databases.	CR 02
2-2	**Representation of data**: Tabular representations of quantitative data, frequency table – one way and two ways.	
2-3	**Graphical representation**: Graphical representation of qualitative data – line graph, histogram, frequency polygon, frequency curve, Ogive, bar diagrams and pie diagrams.	
2-4	**Analysis of data** – Tools of statistics and software applications.	
3-1	**Use of inferential statistical tools in research**: Use of different statistical estimations depending on the type of data, hypothesis testing, and test of significance.	CR 03
3-2	**Biostatical Test**: Student's 't' test – applications and importance in research data And Application of Chi-square test for the experimental data	
3-3	**Use of ANOVA**: (one-way and two-way ANOVA) for the research data analysis.	
3-4	**Application of correlation of data**: Application of correlation and regression analysis for the data.	
4-1	**Literature collection**: Need, review process, consulting source material, literature citation; Components of research report – Text, tables, figures, bibliography, Writing of dissertations, project proposals, project reports, research papers.	CR 04
4-2	**Intellectual Property Rights**: Basics of patent, Types of Patents (patents, copyrights, trademarks, Geographical Indications, Industrial Designs, and traditional knowledge, Patent application process (Searching a patent, Drafting a patent, Filing of patent, Types of patent applications), Patent documents (Specifications and Claims).	
4-3	**Research Databases:** Types of Databases - Indexing Databases and benefits of Indexing, Citation Index Database; Major Citation Indexing Services - Web of Science /Web of Knowledge (WoS/WoK), Scopus/Science Direct, Google Scholar,	

	CiteSeerX, WorldWideScience(WWS), IEEE Xplore, PubMed Central (PMC) Database, Directory of Open Access Journals (DOAJ), Indian Citation Index (ICI) Database, E-Theses Online Service (EThOS), Preprint site arXiv [Refer Chapter 13 of Academic Integrity and Research Quality]	
4-4	**Research Metrics:** Journal Metrics- Impact Factor (IF) or Journal Impact Factor(JIF), List of Impact Factor of Various Journals, Problems of the Impact Factor and the Editorial Ethics, Cite Score, Difference between Cite Score and Impact Factor, Impact Per Publication (IPP); Newly Emerged Indicators - Source Normalised Impact Per Paper (SNIP), Scimago Journal Rank (SJR), Eigenfactor, Article Influence, SCImago Journal; Author level Metrics- H-Index with its Advantages and limitations, G-Index, i10/20 Index; Altmetrics with its Advantages and limitations; Unique ID for Research Contributors/Author. [Refer Chapter 13 and 14 of Academic Integrity and Research Quality]	

LEARNING RESOURCE DETAILS

LR Code	Title Author	Edition Year	ISBN Publisher
Course Website Link for (1) Mobile and Online Lectures, (2) Discussion Forum for online interaction and (3) Self-Test for each CR Block, Continuous Assessment Test and End Examination			
Text-Books			
RES505-T01	Research Methodology (Unit 01 to 14 only), Available here	2022	978-9395855624 YCMOU, Nashik
Reference-Books: Explore additional details and reinforce learning, with this optional learning resource!			
RES505:RB1	Research Methods in Environmental Studies: A Social Science Approach – Ismael Vaccaro, Eric Alden Smith, and Shankar Aswani	1st Edition, 2010	978-0813344113 Routledge
RES505:RB2	Environmental Social Science: Human-Environment Interactions and Sustainability – Emilio F. Moran, Edward A. Rosa, and Anantha K. Duraiappah	1st Edition, 2010	978-1402090346 Springer
RES505:RB3	Handbook of Research Methods and Applications in Environmental Studies – Matthias Ruth and Brynhildur Davidsdottir	1st Edition, 2018	978-1785364327 Edward Elgar Publishing
RES505:RB4	Research Methods for Environmental Studies: A Social Science Approach – Mark L. Nichter and Mimi Nichter	1st Edition, 1991	978-0306438297 Springer
RES505- RB5	Academic Integrity and Research Quality (Chapter 13 and 14)	Dec 2021	e-Books , UGC web site
CD / DVD: Explore additional details and reinforce learning, with this optional learning resource!			
RES505:CD1			
Web Links: Explore additional details and reinforce learning, with this optional learning resource!			
RES505-	Academic Integrity and Research Quality	Dec	UGC

WL1		2021	
RES505-WL2	Guidance Document: Good Academic Research Practices	Sept 2020	UGC
OER: Explore additional details and reinforce learning, with this optional learning resource!			
RES505-OER1			

COURSE OUTCOMES

After successful completion of this course, student will be able to

- Understand some basic concepts of research and its methodologies.
- Select proper method of Data collection & representation
- Select and apply appropriate statistical method for data analysis.
- Perform literature review, research writings with the knowledge of Intellectual Property Rights.

ELECTIVE COURSES

MAT506: OPERATIONS RESEARCH

PROGRAMME INFORMATION

SN	Description	Details
1	University	Yashwantrao Chavan Maharashtra Open University Nashik - 422 222, Maharashtra, India Website: http://www.ycmou.ac.in/and http://ycmou.digitaluniversity.ac/
2	School	School of Sciences
3	Discipline	Science
4	Level	PG
5	Course Used in	V151: M.Sc.(Mathematics) {2023 Pattern} & V130 M.Sc.(Mathematics){2021 Pattern}

COURSE INFORMATION

Sem	Major	Code	Course Name	CR	CST	ST	CA	EE	TM	Type
01	DSE	MAT506	Operations Research	4	12	120	30	70	100	T

PRESUMED KNOWLEDGE AND LEARNING OBJECTIVES

Presumed Knowledge	Learning Objectives
For successful completion of this course, student should have successfully complete: • BSc/BA with Mathematics or equivalent from a recognized University/Board.	The objectives of this course are • To explain the theory of convex sets, functions, formulation of LPP, techniques of integer and non-integer solution of Linear and nonlinear programming problems. • To introduce quantitative methods and techniques for effective decisions–making • To study network analysis: CPM, PERT • To introduce Simulation Theory

UNITS

UN	Name of the Unit	CSs	Questions
01-01 01-02 01-03 01-04	**Basics of Operations Research** **Linear Programming Problems** **The Simplex Method** **Duality**	**CR 01**	As per evaluation pattern, on Each Credit, Student is required to answer • Very Short Answer Question (VSAQ), of 03 marks • Short Answer Question (SAQ), of 05 marks • Long Answer Question (LAQ) of 10 Marks (LAQ may contain sub-questions (a), (b) and so on.)
02-01 02-02 02-03 02-04	**Game Models and Related Theory** **Two Person Zero Sum Game** **Dominance in Games** **Mixed Strategies(2×N and M×2 games)**	**CR 02**	
03-01 03-02 03-03 03-04	**Network Analysis** **Fulkerson's Rule** **Critical Path Method (CPM)** **Programme Evaluation and Review Technique (PERT)**	**CR 03**	

04-01 04-02 04-03 04-04	**Simulations and It's Theory** **Monte Carlo Simulation** **Generation of Random Numbers** **Simulation Languages**	**CR 04**	

DETAILED SYLLABUS

UN	Detailed Syllabus of the Unit	CR
1-1	**Basics of Operations Research**: Definition, Characteristics, Necessity of Operations Research in Industry, Scope of Operations Research.	CR 01
1-2	**Linear Programming Problems:** Formulation of LPP, Graphical Method of LPP solution.	
1-3	**The Simplex Method:** The Standard Form Of L.P. Problem, The Simplex Method (Technique Or Algorithm),The Big M-Method, Two- Phase Method	
1-4	**Duality:** Dual Problem When Primal is in Canonical Form, Dual Problem When Primal Is In The Standard Form, Solution Of Dual Problem, The Dual Simplex Method	
2-1	**Game Models and Related Theory:** Definition, Characteristics of Games, Types of Strategies.	CR 02
2-2	**Two Person Zero Sum Game:** Maximin and Minimax Principles, Saddle Point, Classification of Games, Solution of game with and without saddle point.	
2-3	**Dominance in Games:** Principle of Dominance, Mixed Strategies, Arithmetic Method, Algebraic Method	
2-4	**Mixed Strategies(2×n and m×2 games):**Algebraic method and Subgame method for solving 2×n and m×2 games, Graphic Method For 2×N Games, Graphic Method For M×2 Games	
3-1	**Network Analysis:** Definition, Symbols, Drawing Network diagrams, Analysis of Network diagrams. Errors in Drawing Networks	CR 03
3-2	**Fulkerson's Rule:** Fulkersons Rule, Project Management, Time-Cost Trade-Off Analysis, Time-Cost Optimization/Network Crashing	
3-3	**Critical Path Method (CPM):** Labelling Method for Determination of Critical Path, Method Based on Time Estimates to Find Critical Path, Slack and Floats in Network Analysis	
3-4	**Project Evaluation and Review Technique (PERT):**PERT, PERT Analysis, Requirements and Practical Limitations of PERT, Comparison of CPM And PERT	
4-1	**Simulations and It's Theory:** Introduction too Simulation, Advantages of The Simulation Technique, Limitations of The Simulation Technique, Applications of Simulation	CR 04
4-2	**Monte Carlo Simulation:** Simulation of Inventory Problems, Simulation of Queuing Problem, Simulation of Investment and Budgeting, Job Sequencing Problem, Simulation of Maintenance Problem	
4-3	**Generation of Random Numbers:** Mid-Square Method, Mixed Congruence Method, Additive Congruential Method, Multiplicative Congruential Method	
4-4	**Simulation Languages:** Simulation Languages	

LEARNING RESOURCE DETAILS

LR Code	Title Author	Edition Year	ISBN Publisher
Course Website Link for (1) Mobile and Online Lectures, (2) Discussion Forum for online interaction and (3) Self-Test for each CR Block, Continuous Assessment Test and End Examination			
CW-MAT506			
Text-Books			
MAT506-T01	Operations Research, Dr. Subhash G. Pawar&Ms. Chetana V. Visave	2021	978-93-92982-16-3 YCMOU
Reference-Books: Explore additional details and reinforce learning, with this optional learning resource!			
MAT506 – RB1	Operations Research, P. K. Gupta and D. S. Hira		S Chand and Company Limited, New Delhi.
MAT506 – RB2	Operations Research An Introduction, Taha	9th Edition	Pearson
MAT506 – RB3	Operations Research, B. S. Goel, S. K. Mittal,		Pragati Prakashan
MAT506 – RB4	Linear Programming, G. Hardley,		Oxford and IBH Publishing Co
MAT506 – RB5	Operations Reearch, J. K. Sharma	6th Edition 2017	
CD / DVD: Explore additional details and reinforce learning, with this optional learning resource!			
MAT506 - CD1			
Web Links: Explore additional details and reinforce learning, with this optional learning resource!			
MAT506-WL1			

COURSE OUTCOMES

After successful completion of this course, student should be able to

- Understand the theory of convex sets, functions, formulation of LPP, techniques of integer and non-integer solution of Linear and nonlinear programming problems.
- Use quantitative methods and techniques for effective decisions– making
- Develop model formulation and applications that are used in solving business decision problems.

MAT507: NUMERICAL ANALYSIS

PROGRAMME INFORMATION

SN	Description	Details
1	University	Yashwantrao Chavan Maharashtra Open University Nashik - 422 222, Maharashtra, India Website: http://www.ycmou.ac.in/and http://ycmou.digitaluniversity.ac/
2	School	School of Sciences
3	Discipline	Science
4	Level	PG
5	Course Used in	V151: M.Sc.(Mathematics) {2023 Pattern} & V130 M.Sc.(Mathematics){2021 Pattern}

COURSE INFORMATION

Sem.	Major	Code	Course Name	CR	CST	ST	CA	EE	TM	Type
01	DSE	MAT507	Numerical Analysis	4	12	120	30	70	100	T

PRESUMED KNOWLEDGE AND LEARNING OBJECTIVES

Presumed Knowledge	Learning Objectives
For successful completion of this course, student should have successfully complete: • BSc/BA with Mathematics or equivalent from a recognized University/Board.	The objectives of this course are • To explain numerical method to solve algebraic or transcendental equations using an appropriate numerical method • To illustrate numerical method to solve linear systems of equations • To study the techniques of numerical methods to solve ordinary differential equations.

UNITS

UN	Name of the Unit	CSs	Questions
01-01 01-02 01-03 01-04	**Errors in Numerical Calculations** **Solutions of algebraic and transcendental equations** **Newton Raphson method** **Interpolation**	**CR 01**	As per evaluation pattern, on Each Credit, Student is required to answer • Very Short Answer Question (VSAQ), of 03 marks • Short Answer Question (SAQ), of 05 marks • Long Answer Question (LAQ) of 10 Marks (LAQ may contain sub-questions (a), (b) and so on.)
02-01 02-02 02-03 02-04	**Matrices** **Systems of Linear Algebraic equations** **Methods of solving systems of linear equations** **Iteration methods**	**CR 02**	
03-01 03-02 03-03 03-04	**Numerical Differentiation** **Methods based on undetermined coefficients** **Numerical integration: Methods based on finite differences, Trapezoidal rule, Simpson's 1/3 rule and Simpson's 3/8 rule** **Numerical integration: Methods based on undetermined coefficients**	**CR 03**	

04-01 04-02 04-03 04-04	**Solutions of ordinary differential equations by Taylor's Series, Picard's and Euler's Method** **Runge - Kutta Methods** **Simultaneous and higher order equations** **Solutions of partial differential equations**	**CR 04**	

DETAILED SYLLABUS

UN	Detailed Syllabus of the Unit	CR
1-1	**Errors in Numerical Calculations:** Approximate numbers and significant digits, rounding off numbers, absolute, relative and percentage errors.	**CR 01**
1-2	**Solutions of algebraic and transcendental equations:** Introduction, Bisection method, Iteration method, method of false position.	
1-3	**Newton Raphson method:** Newton Raphson method, generalized Newton's method.	
1-4	**Interpolation:** Finite differences- forward differences, backward differences, Newton's forward difference formula, Newton's backward difference formula.	
2-1	**Matrices:** Basic Definitions, Inverse of a matrix, rank of a matrix.	**CR 02**
2-2	**Systems of Linear Algebraic equations:** Introduction, linear systems of Equations, consistency of linear systems of Equations.	
2-3	**Solutions of Linear Systems:** Direct methods-Matrix inversion methods, Gauss Elimination method, Gauss -Jordan Elimination method, Triangularization method.	
2-4	**Iterative methods:** Jacobi iteration method, Gauss Seidal iteration method	
3-1	**Numerical Differentiation:** Methods based on Interpolation, Methods based on finite differences, Newton's forward difference formula, Newton's backward difference formula	**CR 03**
3-2	**Methods based on undetermined coefficients:** Maximum and minimum values of a function, numerical partial differentiation	
3-3	**Numerical Integration:** The Newton - Cotes Integration formulas, Trapezoidal rule, Simpson's $1/3^{rd}$rule, Simpson's $3/8^{th}$rule, Boole's and Weddle's Rules,	
3-4	**Numerical integration: Methods based on undetermined coefficients:**	
4-1	**Solutions of ordinary differential equations by Taylor's Series, Picard's and Euler's Method:** Numerical methods to solve an ordinary differential equation: Taylor's Series Method: Picard's Method of Successive Approximations, Euler's Method, Modified Euler's Method	**CR 04**
4-2	**Runge - Kutta Methods:** Runge -Kutta formula, Predictor - Corrector Methods, Adams - Moulton Method, Milne's Method	
4-3	**Simultaneous and higher order equations:** Solution of Simultaneous first order D.E., Higher order equations, Finite Difference Method	
4-4	**Solutions of partial differential equations:** Diagonal five–point formula, Jacobi's Method, Gauss–Seidel Method, Successive Over–Relaxation Method	

LEARNING RESOURCE DETAILS

LR Code	Title Author	Edition Year	ISBN Publisher
Course Website Link for (1) Mobile and Online Lectures, (2) Discussion Forum			

for online interaction and (3) Self-Test for each CR Block, Continuous Assessment Test and End Examination			
CW-MAT507			
Text-Books			
MAT507-To1	Numerical Analysis, Dr. Meenakshi Wasadikar & Dr. S. K. Nimbhorkar	2020	978-93-91514-54-9 YCMOU
Reference-Books: Explore additional details and reinforce learning, with this optional learning resource!			
MAT507 – RB1	Introductory methods of Numerical Analysis, S. S. Sastry	4th	Prentice Hall
MAT507 – RB2	Numerical methods for scientific and engineering computation. Jain, Iyengar and Jain	4th Edition	New Age Publication, New Delhi
MAT507 – RB3	Numerical method & Analysis, J. I. buchaman and P. R. Turner		Prentice Hall
MAT507 – RB4	Numerical Methods for Engineers by Steven C. Chapra and Raymond P.Canale,	2009	Tata McGraw Hill, New Delhi
CD / DVD: Explore additional details and reinforce learning, with this optional learning resource!			
MAT507 - CD1			
Web Links: Explore additional details and reinforce learning, with this optional learning resource!			
MAT507-WL1			

COURSE OUTCOMES

After successful completion of this course, student should be able to

- Find solutions of algebraic or transcendental equations using an appropriate numerical method
- Solve linear systems of equations using an appropriate numerical method
- Apply the techniques of numerical methods to solve ordinary differential equations.

SEMESTER 02

MAT509: TOPOLOGY

PROGRAMME INFORMATION

SN	Description	Details
1	University	Yashwantrao Chavan Maharashtra Open University Nashik - 422 222, Maharashtra, India Website: http://www.ycmou.ac.in/and http://ycmou.digitaluniversity.ac/
2	School	School of Sciences
3	Discipline	Science
4	Level	PG
5	Course Used in	V151: M.Sc.(Mathematics) {2023 Pattern} & V130 M.Sc.(Mathematics){2021 Pattern}

COURSE INFORMATION

Sem	Major	Code	Course Name	CR	CST	ST	CA	EE	TM	Type
02	DSC	MAT509	Topology	4	12	120	30	70	100	T

PRESUMED KNOWLEDGE AND LEARNING OBJECTIVES

Presumed Knowledge	Learning Objectives
For successful completion of this course, student should have successfully complete: • BSc/BA with Mathematics or equivalent from a recognized University/Board.	The objectives of this course are • To study concept of Topological spaces • To explain connected and compact spaces • To elaborate Countability & separation axioms

UNITS

UN	Name of the Unit	CSs	Questions
01-01 01-02 01-03 01-04	**Topological spaces** **Basis and Subbasis for a topology** **Product and subspace topologies** **Limit points**	**CR 01**	As per evaluation pattern, on Each Credit, Student is required to answer • Very Short Answer Question (VSAQ), of 03 marks • Short Answer Question (SAQ), of 05 marks • Long Answer Question (LAQ) of 10 Marks (LAQ may contain sub-questions (a), (b) and so on.)
02-01 02-02 02-03 02-04	**Continuous functions** **Quotient spaces** **Connected spaces** **Locally connected spaces**	**CR 02**	
03-01 03-02 03-03 03-04	**Compact spaces** **Forms of compact spaces** **Countability axioms** **Lindelöf spaces**	**CR 03**	
04-01 04-02 04-03 04-04	**Separation axioms** **Regular and normal spaces** **The Urysohn lemma** **Compactification**	**CR 04**	

DETAILED SYLLABUS

UN	Detailed Syllabus of the Unit	CR
1-1	**Topological spaces:** Definition and examples of topological space,	CR 01
	Basis and Subbasis for a topology: Basis for a topology, finer and coarser topological spaces, subbasis	
1-2	**Product and subspace topologies**: Order topology, Product topology on $X \times Y$, Subspace topology	
1-3	**Limit points**: closed sets and limit points, closure and Interior, Hausdörff spaces	
2-1	**Continuous functions**: Continuity of a function, Homeomorphism, Pasting lemma,	CR 02
2-2	**Quotient spaces**: Product topology, Metric topology, Quotient topology	
2-3	**Connected spaces**: separations, Connected sets, Cartesian product of connected sets,	
2-4	**Locally connected spaces**: components and path components, locally connected sets.	
3-1	**Compact spaces:** Compact sets, Hausdörff spaces and Compact sets, continuity and connected sets, Finite intersection property.	CR 03
3-2	**Forms of compact spaces:** Limit point compact sets, sequentially compact sets, countably compact sets, locally compact sets.	
3.3	**Countability axioms**: First countable axiom, second countable axiom, dense sets.	
3.4	**Lindelöf spaces:** Separable space,Lindelöf space.	
4-1	**Separation axioms**: T_0, T_1, T_2 spaces	CR 04
4-2	**Regular and normal spaces**: T_3, $T_{3\frac{1}{2}}$ spaces, regular spaces and Normal spaces	
4-3	**Urysohn lemma**: Urysohn's lemma, Tiesz extension theorem.	
4-4	**Compactification**: Completely regular spaces, Stone-Cech compactification.	

LEARNING RESOURCE DETAILS

LR Code	Title Author	Edition Year	ISBN Publisher
Course Website Link for (1) Mobile and Online Lectures, (2) Discussion Forum for online interaction and (3) Self-Test for each CR Block, Continuous Assessment Test and End Examination			
CW-MAT509			
Text-Books			
MAT509-T01	Topology Dr. B. Surendranath Reddy & Dr. D. D. Pawar	2020	978-93-91514-53-2 YCMOU
Reference-Books: Explore additional details and reinforce learning, with this optional learning resource!			
MAT509 – RB1	Topology: First course, J R Munkres	2000	Prentice Hall Inc., New Jersey
MAT509 – RB2	Theory and Problems of Set Theory and Related Topics,		Schaum Publishing Co. New York

	Lipshutz Seymour		
MAT509 – RB3	Foundations of General Topology, Pervin William J		Academic Press
MAT509 – RB4	Elementary Topology, D. W. Hall and 0. L. Spencer.	1955	John Wiley & Sons
MAT509 – RB5	Topology, J. Dugundji	1966	Allyn and Bacon, Boston
CD / DVD: Explore additional details and reinforce learning, with this optional learning resource!			
MAT509 - CD1			
Web Links: Explore additional details and reinforce learning, with this optional learning resource!			
MAT509-WL1			

COURSE OUTCOMES

After successful completion of this course, student should be able to

- Understand the basic concepts of topology and base for the topology
- Discuss continuity of functions in topological spaces
- Apply countability axioms for discussion of compactness, connectedness and sequential continuity of functions.

MAT510: Linear Algebra

Programme Information

SN	Description	Details
1	University	Yashwantrao Chavan Maharashtra Open University Nashik - 422 222, Maharashtra, India Website: http://www.ycmou.ac.in/and http://ycmou.digitaluniversity.ac/
2	School	School of Sciences
3	Discipline	Science
4	Level	PG
5	Course Used in	V151: M.Sc.(Mathematics) {2023 Pattern} & V130 M.Sc.(Mathematics){2021 Pattern}

Course Information

Sem	Major	Code	Course Name	CR	CST	ST	CA	EE	TM	Type
02	DSC	MAT510	Linear Algebra	4	12	120	30	70	100	T

Presumed Knowledge and Learning Objectives

Presumed Knowledge	Learning Objectives
For successful completion of this course, student should have successfully complete: • BSc/BA with Mathematics or equivalent from a recognized University/Board.	The objectives of this course are • To comprehend generalized notion of vectors and their properties, dual spaces, inner product spaces and modules. • To explain properties of linear transformations, characteristic roots, matrix corresponding to linear transformation and their canonical forms. • To depict properties of determinants, linear operators and quadratic forms.

Units

UN	Name of the Unit	CSs	Questions
01-01 01-02 01-03 01-04	**Vector Spaces** **Dual spaces** **Inner product spaces** **Modules**	CR 01	As per evaluation pattern, on Each Credit, Student is required to answer • Very Short Answer Question (VSAQ), of 03 marks • Short Answer Question (SAQ), of 05 marks • Long Answer Question (LAQ) of 10 Marks (LAQ may contain sub-questions (a), (b) and so on.)
02-01 02-02 02-03 02-04	**Linear transformations** **Characteristic roots** **Matrices** **Triangular forms**	CR 02	
03-01 03-02 03-03 03-04	**Nilpotent forms** **Jordan form** **Rational Canonical form** **Trace and transpose of a matrix**	CR 03	
04-01 04-02 04-03 04-04	**Determinants** **Operators** **Normal operator** **Real Quadratic forms**	CR 04	

DETAILED SYLLABUS

UN	Detailed Syllabus of the Unit	CR
1-1	**Vector Spaces: (**Preliminaries on vector spaces, Linear independence and base)Direct product of subspaces, Homomorphism, Isomorphism theorems,	CR 01
1-2	**Dual Spaces**: Theorems related to Hom(V, W), Dual space of a vector space, Annihilator.	
1-3	**Inner product spaces:** Inner product, Gram-Schmidt normalization process	
1-4	**Modules:** Submodules, fundamental theorem of finitely generated modules over Euclidean rings, homomorphisms, irreducible modules.	
2-1	**Linear transformations:** Algebra of Linear transformations, Minimal polynomial of a Linear Transformation, Invertible Linear transformation. Rank of linear transformation.	CR 02
2-2	**Characteristic roots:** Idempotent, nilpotent linear transformations, characteristic roots.	
2-3	**Matrices:** Matrix of a Linear Transformation, Relation between algebras of $n \times n$ matrices and set of matrices related to linear transformations.	
2-4	**Triangular form:** Triangular form of a linear transformation, invariant subspaces, Theorems on triangular form.	
3-1	**Nilpotent forms:** Theorems related nilpotent linear transformation, Invariants of a linear transformation, cyclic subspace under Linear transformation,	CR 03
3-2	**Jordan form:** Jordan block, Jordan form diagonalizable matrix.	
3-3	**Rational Canonical form:** Companion matrix of a polynomial, rational canonical form of a linear transformation, elementary divisors of a linear transformation.	
3-4	**Trace and transpose of a matrix:** trace, transpose, symmetric matrix, skew symmetric matrix, adjoint.	
4-1	**Determinants:** Determinants of a matrix, properties of determinant, characteristic polynomials and roots.	CR 04
4-2	**Operators:** Hermitian, Unitary transformations and their properties. Operators and Their Matrices.	
4-3	**Normal operator:** Adjoint and normal operator. Properties of Normal operator, Its relationship with unitary and Hermite transformation, Orthogonal Projections and the Spectral Theorem.	
4-4	**Real Quadratic forms:** Bilinear and Quadratic Forms.	

LEARNING RESOURCE DETAILS

LR Code	Title Author	Edition Year	ISBN Publisher
Course Website Link for (1) Mobile and Online Lectures, (2) Discussion Forum for online interaction and (3) Self-Test for each CR Block, Continuous Assessment Test and End Examination			
CW-MAT510			
Text-Books			
MAT510-T01	Linear Algebra, Dr. J. N. Chaudhari &Dr. N. S. Darkunde	2021	978-93-91514-60-0 YCMOU
Reference-Books: Explore additional details and reinforce learning, with this optional			

learning resource!			
MAT510 – RB1	Topics in Algebra, Herstein I N	1975	Wiley Eastern Ltd.New Delhi,
MAT510 – RB2	A First Course In Abstract Algebra, J. B. Fraleigh	1970	Addison-wesley
MAT510 – RB3	University Algebra, N.S. Gopalakrishnan	1986	2nd Edition, New Age publishers,
MAT510 – RB4	Abstract Algebra, David S. Dummit and Richard M. Foote	3rd Edition 2003	Wiley International Ltd
MAT510 – RB5	Algebra, M. Artin	1996	Eastern Economy Edition
CD / DVD: Explore additional details and reinforce learning, with this optional learning resource!			
MAT510 - CD1			
Web Links: Explore additional details and reinforce learning, with this optional learning resource!			
MAT510-WL1			

COURSE OUTCOMES

After successful completion of this course, student should be able to

- Develop concepts of vector spaces and modules
- Solve problems based on Linear transformations and Characteristic roots
- Construct matrices in Nilpotent, Jordan and Rational forms which are useful for solving system of equations
- Visualize the adjoint, self-adjoint and normal linear trans formations

MAT511: Partial Differential Equations

Programme Information

SN	Description	Details
1	University	Yashwantrao Chavan Maharashtra Open University Nashik - 422 222, Maharashtra, India Website: http://www.ycmou.ac.in/and http://ycmou.digitaluniversity.ac/
2	School	School of Sciences
3	Discipline	Science
4	Level	PG
5	Course Used in	V151: M.Sc.(Mathematics) {2023 Pattern} & V130 M.Sc.(Mathematics){2021 Pattern}

Course Information

Sem	Major	Code	Course Name	CR	CST	ST	CA	EE	TM	Type
02	DSC	MAT511	Partial Differential Equations	2	6	60	15	35	50	T

Presumed Knowledge and Learning Objectives

Presumed Knowledge	Learning Objectives
For successful completion of this course, student should have successfully complete: • BSc/BA with Mathematics or equivalent from a recognized University/Board.	The objectives of this course are • To improve problem solving and logical thinking abilities related to solution of partial differential equations • To study a range of techniques to solve partial differential equations first order and second order. • To explain Charpit's Method, Jacobi Method.

Units

UN	Name of the Unit	CSs	Questions
01-01 01-02 01-03 01-04	**Ordinary Differential Equations** **Orthogonal Trajectories** **Partial Differential Equations of the First Order** **Cauchy's Problem for First -order Equations**	**CR 01**	As per evaluation pattern, on Each Credit, Student is required to answer • Very Short Answer Question (VSAQ), of 03 marks • Short Answer Question (SAQ), of 05 marks • Long Answer Question (LAQ) of 10 Marks (LAQ may contain sub-questions (a), (b) and so on.)
02-01 02-02 02-03 02-04	**Nonlinear Partial Differential Equations of the First Order** **Jacobi's Method** **Partial differential equations of the second order** **Linear Partial Differential Equations with Constant Coefficients**	**CR 02**	

Detailed Syllabus

UN	Detailed Syllabus of the Unit	CR
1-1	**Ordinary Differential Equations**: Surfaces and Curves in Three Dimensions, Simultaneous Differential Equations of the First Order and the First Degree in Three Variables, Methods of Solution of $\frac{dx}{P} = \frac{dy}{Q} = \frac{dz}{R}$.	**CR 01**

1-2	**Orthogonal Trajectories:** Orthogonal Trajectories of a System of Curves on a Surface, Pfaffian Differential Forms and Equations, Solution of Pfaffian Differential Equations in Three Variables.	
1-3	**Partial Differential Equations of the First Order:** PDEs, Origins of First -order Partial Differential Equations, Linear Equations of the First Order.	
1-4	**Cauchy's Problem for First -order Equations:** Integral Surfaces Passing through a Given Curve, Surfaces Orthogonal to a Given System of Surfaces.	
2-1	**Nonlinear Partial Differential Equations of the First Order**: Cauchy's Method of Characteristics, Compatible Systems of First-order Equations, Charpit's Method, Special Types of First-order Equations, Solutions Satisfying Given Conditions.	**CR 02**
2-2	**Jacobi's Method**: Jacobi's Method for Nonlinear Partial Differential Equations of the First Order, Applications of First -order Equations.	
2-3	**Partial differential equations of the second order:** The Origin of Second-order Equations, Second -order Equations in Physics, Higher-order Equations in Physics.	
2-4	**Linear Partial Differential Equations with Constant Coefficients**: Theorems on Equations with Constant Coefficients.	

LEARNING RESOURCE DETAILS

LR Code	Title Author	Edition Year	ISBN Publisher
Course Website Link for (1) Mobile and Online Lectures, (2) Discussion Forum for online interaction and (3) Self-Test for each CR Block, Continuous Assessment Test and End Examination			
CW-MAT511			
Text-Books			
MAT511-T01	Partial Differential Equations, H. L. Tidke &Dr. J N Salunke	2021	978-93-92982-15-6 YCMOU
Reference-Books: Explore additional details and reinforce learning, with this optional learning resource!			
MAT511 – RB1	Elements of Partial Differential Equations, Ian N. Sneddon	1957	McGraw-Hill International Edition, New Delhi
MAT511 – RB2	An Elementary Course in Partial Differential Equations, T. Amaranath	2nd 2003	Narosa Publishing House Pvt. Ltd, New Delhi
CD / DVD: Explore additional details and reinforce learning, with this optional learning resource!			
MAT511 - CD1			
Web Links: Explore additional details and reinforce learning, with this optional learning resource!			
MAT511-WL1			

COURSE OUTCOMES

After successful completion of this course, student should be able to

- Solve the first-order linear and non-linear partial differential equations by using Lagrange's and Charpit's methods respectively.
- Understand concepts, methods of Solutions and applications of Partial Differential equations.

MAT512: LaTeX and Programming in SageMath

Programme Information

SN	Description	Details
1	University	YashwantraoChavan Maharashtra Open University Nashik - 422 222, Maharashtra, India Website: http://www.ycmou.ac.in/and http://ycmou.digitaluniversity.ac/
2	School	School of Sciences
3	Discipline	Science
4	Level	PG
5	Course Used in	V151: M.Sc.(Mathematics) {2023 Pattern}

Course Information

Sem	Major	Code	Course Name	CR	CST	ST	CA	EE	TM	Type
02	DSC	MAT512	LaTex and Programming in SageMath	4	12	120	50	50	100	P

Presumed Knowledge and Learning Objectives

Presumed Knowledge	Learning Objectives
For successful completion of this course, student should have successfully complete: • BSc/BA with Mathematics or equivalent from a recognized University/Board.	The objectives of this course are • To provide an understanding of the basic mechanisms of LaTeX • To acquaint students with the latest typesetting skills • To equip students with a powerful mathematical tool • To solve equations and performing computations to exploring complex mathematical structures and visualizing data • To Explore mathematical concepts through interactive computations, visualizations, and simulations

Note: (1) The theoretical background relevant to the experiments listed below should be discussed during practical sessions only.
(2) Wherever possible, the output should be presented in graphical form also.

Lab Activity

SN	Title of Activity	CR
1	Introduction to LaTeX	CR 01
2	Syntax and Keyboard Characters, Fonts in LaTeX	
3	Sections, Labelling and Text Alignment, New Lines, Paragraphs, Blank Space and Dashes in LaTeX	
4	Listing Texts –I, Listing Texts –II, Tabbing TextsinLaTeX	
5	Table Through the tabular Environment, tabularxEnvironmentinLaTeX	
6	Positioning and Texts in Tables, Customizing Tables in LaTeX	
7	Commands and Environment for Inserting FiguresinLaTeX	CR 02
8	Mathematical Notations, Operators and Expression in LaTeX	

9	Simple Equations, Array of Equations, Alignment and numbering a Set of Equations in LaTeX	
10	Texts, Blank Space and Conditional Expression in Math mode in LaTeX	
11	Vector and Matrix in LaTeX	
12	New Commands, New Environments in LaTeX	
13	Introduction & Installation: What & Why Sage, Installing Sage, The Jupyter Notebook, Resources	
14	Elementary Algebra using Sage: Basic arithmetic operations in Sage, Integer operations in Sage, Predefined constants in Sage, Usual mathematical functions in Sage Math	
15	Symbolic variables, expressions and simplification: Define Symbolic variables, Expressions containing variables like x + y + z or sin(x) + cos(x), Perform analytic computations on symbolic expressions in Sage, Use of Simplification command in SageMath	
16	Solving Equations in SageMath: Solve Equations with explicit solution- Solve scalar equations, vector and functional equations using solve command, Solve Equations with no explicit solution in SageMath	**CR 03**
17	Calculus in SageMath: Sums, Limits, Sequences, Series, Derivatives, Derivatives, Integrals using SageMath	
18	Working with vectors and Matrices in SageMath: Define vectors and perform basic vector computations, define matrix and perform basic Matrix computations in SageMath	
19	Basic Linear Algebra in SageMath: Perform elementary row transformations, Solve Linear System of Equations using Matrices, Check linear independence and dependence of vectors	
20	Programming in SageMath: Syntax, Algorithmic, Lists, Functions, Conditionals, Loops- for loop, while loop	
21	2D Graphics in SageMath: Graphical Representation of a Function, Parametric Curve, Curve in Polar Coordinates, Curve Defined by an Implicit	
22	3D Graphics in SageMath: 3D graphical capabilities of Sage, Graphical Representation of surface corresponding to a 2-variable function, surfaces in 3-dimensions using SageMath	**CR 04**
23	Differential Equations in SageMath: First and Second order Differential Equations, Laplace Transform, Displaying Solutions of Differential Equations	
24	Group Theory using SageMath: Define and study the properties of various types of groups-integers modulo n, symmetric group, dihedral group, alternating group, subgroups, normal groups in SageMath	

LEARNING RESOURCE DETAILS

LR Code	Title Author	Edition Year	ISBN Publisher
Text-Books			
Reference-Books: Explore additional details and reinforce learning, with this optional learning resource!			

MAT 512 RB1	LaTeX in 24 Hours, A Practical Guide for Scientific Writing, DilipDatta,	2017	Springer International Publishing AG
MAT 512 RB2	Latex Tutorials — A Primer, E. Krishnan and G. S. Krishna	2003	Indian TEX Users Group Floor III, SJP Buildings, Cotton Hills Trivandrum
MAT 512 RB3	Handbook of writing for the mathematical sciences, Higham Nicholas J.,	1961	SIAM
MAT 512 RB4	LaTeX, A Document Preparation System, User's Guide and Reference Manual, Leslie Lamport,	1994	Addison-Wesley Publishing Company
MAT 512 RB5	LaTeX Beginner's Guide, Stefan Kottwitz,	2011	Packt Publishing Ltd
MAT 512 RB6	LaTeX and Friends, M.R.C. van Dongen,	2012	Springer-Verlag Berlin Heidelberg
MAT 512 RB7	Math into LaTeX, George Gratzer,	1996	Springer Science Business Media New York
MAT 512 – RB8	Mathematical Computation with SageMath http://dl.lateralis.org/public/sagebook/sagebook-ba6596d.pdf	2018	
MAT 512 – RB9	Sage for Undergraduates	2010	978-1-4704-2042-0 AMS
MAT 512 – RB10	Sage for Linear Algebra A Supplement to A First Course in Linear Algebra		
CD / DVD: Explore additional details and reinforce learning, with this optional learning resource!			
-CD1			
Web Links: Explore additional details and reinforce learning, with this optional learning resource!			
MAT 512 – WL1	Link o IITBSpoken Tutorial for LATEX: LaTeX on Windows using TeXworks - English - YouTube LaTeX101x S101 Overview - YouTube		
MAT 512 – WL2	SageMath - Open-Source Mathematical Software System		
MAT 512 – WL3	Tutorial (sagemath.org)		
MAT 512 – WL4	https://ajitmathsoft.wordpress.com/sagemath/		
MAT 512 – WL5	https://www.youtube.com/watch?v=VPAALHYIwAI		

COURSE OUTCOMES

After successful completion of this course, student should be able to

- Write a simple LaTeX input document based on the article class
- Turn the input document into pdf with the pdflatex program
- Format Words, Lines, and Paragraphs
- Understand how to present data using tables

- Typeset mathematical formulas, use nested list, tabular and array environments.
- Import figures and pictures that are stored in external files
- Apply computational domains to perform symbolic computations effectively
- Perform algebraic operations using SageMath
- Perform matrix operations and computations using SageMath
- Solve first-order, Second order ordinary differential equations using appropriate methods in SagMath
- Represent curves, surfaces, equations graphically using SageMath
- Explore various concepts in Group Theory using SageMath

MAT513: On Job Training (OJT)

Programme Information

SN	Description	Details
1	University	Yashwantrao Chavan Maharashtra Open University Nashik - 422 222, Maharashtra, India Website: http://www.ycmou.ac.in/and http://ycmou.digitaluniversity.ac/
2	School	School of Sciences
3	Discipline	Science
4	Level	PG
5	Course Used in	V151: M.Sc.(Mathematics) {2023 Pattern}

Course Information

Sem	Other	Code	Course Name	CR	CST	ST	CA	EE	TM	Type
02	OJT	MAT513	On Job Training	4	12	120	50	50	100	TW

Presumed Knowledge and Learning Objectives

Presumed Knowledge	Learning Objectives
For successful completion of this course, student should have successfully complete: • BSc/BA with Mathematics or equivalent from a recognized University/Board.	The objectives of this course are • To Provide opportunities to learn, understand and sharpen the required skills at the job with hands-on experiences • To provide an effective training environment to students • To provide opportunities for students to apply theories and principles learned in class to real job settings. • To bridge the gap between academia and the professional world • To promote research and innovation

Details About ON-JOB-TRAINING (OJT)/Internships

Internships offer valuable opportunities for postgraduate students to bridge the gap between academia and the professional world, promote research and innovation.

By engaging in hands-on experiences and collaborating with experts, students can develop practical skills, expand their network, and gain insights into potential career paths.

Guidelines: [In process]

A. General:

1) It is mandatory for a student to successfully complete the OJT (Internship) for the award of the PG Diploma / PG Degree. This internship could be the research internship or any normal industry, Organization/Institute, Start-up/ ATAL Innovation/Incubation centers, Micro/Small/Medium/Enterprise, Govt/NGO/PSU/, Online/offline academic activities at School/Regional Centers/ University Head Quarters, Online Internship related to major courses.
2) In case of working students if his/her job nature is related to major courses or in allied domain then he/she will be permitted for the internship at workplace provided; a declaration by an employer is submitted directly to the LSC head and School. Both,

declaration by an employer and the training completion certificate will be attached along with Internship report.

3) Internship is of four credits with a period of 4 weeks and carries a weightage of 50-50% in 'Continuous Assessment (CA)' and 'End examination (EE)'. The internship time period does not extend beyond end examination of OJT.
    - Total Study efforts (including Self-Study) in Hours: Total 120 Hours
    - On-Job-Training/Internship (@during 22working days) in a month: minimum 110Hours
    - Preparation of Internship Report: 10 Hours
    - Duration– i) After end examination of semester 02 and before beginning of semester 03 or
      ii) Any one month within semester 02 of the programme
4) At the end of the internship, each student is required to provide a printed copy of their consolidated diary/journal and internship report for the evaluation of internship. The report must express exactly what was learned and accomplished during the internship.
5) The Intern will be assessed by
    a) Continuous Assessment (CA)
        - Mentor of the Industry/NGO/organization/Institute etc where student is selected for Internship
    b) End Examination (EE)
        - LSC Supervisor/PC and External Examiner.

B. Monitoring and Evaluation:

Monitoring: During internship period as part of 'Continuous assessment (CA)', the mentor should evaluate the interns using the following points and should issue a recommendation letter that whether Intern/student meets the expectations of the internship or not:

1	Behaviors, Shows interest in assigned work, Willingness to learn
2	Accepts responsibility, Cooperates with co-workers and supervisors, Demonstrates organizational skills
3	Uses time, knowledge and expertise effectively, Analyzes problems effectively
4	Demonstrates creativity/ originality / any innovative contribution, Professional ethics and accountability
5	Writes effectively, Produces high quality work/Skill Proficiency

Evaluation: At internship, the intern will be evaluated in the end examination (EE), by aduly constituted expert committee of internal and external, on the following suggestive aspects:

- Professional Attitude
- Maintenance of Daily Diary
- Internship Report
- Viva voce/Oral

Reference-Link: Explore additional details!	
MAT 513 – RL 1	UGC Internship Guidelines https://www.ugc.gov.in/pdfnews/1887287_Rsearch-Internship-Guidelines-120522.pdf
MAT 513 – RL 2	AICTE Internship Portal https://internship.aicte-india.org/
MAT 513 – RL 3	NITI Aayog Internship Scheme https://www.niti.gov.in/internship

COURSE OUTCOMES

After successful completion of this course, student should be able to –

- Demonstrate proficiency in solving complex mathematical problems encountered in real-world scenarios within their field of specialization.
- Apply advanced mathematical concepts, theories, and techniques to solve practical problems in various industries such as finance, engineering, data science, and computer science.
- Develop strong research and analytical skills, including the ability to critically evaluate mathematical models, algorithms, and data analysis techniques.
- Communicate mathematical concepts and findings effectively to both technical and non-technical audiences through written reports, presentations, and discussions
- Work effectively as part of a multidisciplinary team, leveraging their mathematical expertise to contribute to the overall objectives of the project or organization.
- Acquire project management skills, including planning, organizing, and executing mathematical projects effectively, within scope, budget, and timeline constraints.
- Develop critical thinking skills to identify mathematical problems, formulate hypotheses, and devise appropriate strategies for problem-solving.
- Gain hands-on experience working on real-world projects in collaboration with industry partners, applying their mathematical knowledge to address industry-specific challenges.

MAT514: Field Project (FP)

Programme Information

SN	Description	Details
1	University	Yashwantrao Chavan Maharashtra Open University Nashik - 422 222, Maharashtra, India Website: http://www.ycmou.ac.in/and http://ycmou.digitaluniversity.ac/
2	School	School of Sciences
3	Discipline	Science
4	Level	PG
5	Course Used in	V151: M.Sc.(Mathematics) {2023 Pattern}

Course Information

Sem	Other	Code	Course Name	CR	CST	ST	CA	EE	TM	Type
02	FP	MAT514	Field Project	4	12	120	50	50	100	TW

Presumed Knowledge and Learning Objectives

Presumed Knowledge	Learning Objectives
For successful completion of this course, student should have successfully complete: • BSc/BA with Mathematics or equivalent from a recognized University/Board.	The objectives of this course are • Apply theoretical knowledge in real-world settings • Develop research and investigative skills • Conduct independent research • Collaborate and communicate effectively • Develop problem-solving and critical thinking abilities

Details about Field Project (FP) [In process]

Domains

Maharashtra is a diverse state with various Industries such as Agricultural, Finance, Hospitality, Health care, Construction, Food, Chemical, Electronic, Manufacturing, and Transportation etc. Various social, economic, environmental challenges faced by these industries to provide research opportunities. Choose a domain that aligns with your interests, the expertise of your faculty, and the resources available in your region. Field projects offer an opportunity to apply theoretical knowledge to real-world situations and contribute to address social, environmental, economical challenges in the region. Some potential domains of field work for Mathematics students are listed as follows. Learner may find this helpful while choosing topic of the field work, but not limited to –

- **Agricultural Sector:** Conduct Agricultural Survey in rural areas of Maharashtra to study various problems associated with this sector through data collection, optimization techniques.
- **Finance Sector:** Study the working strategies and problems faced in Finance sector.
- **Manufacturing Sector:** Study the working strategies in Statistical Quality Control, Inventory Control departments of the Manufacturing industry nearby you.

- **Insurance Sector:** Study the working strategies and problems faced in Insurance sector.
- **Health Care:** Apply Mathematical Modelling to solve the problems in the Health care sector.
- **Chemical Sector:** Study the Environmental issues concerned with this Industry by using Mathematical Modelling and optimization techniques.
- **Construction:** Study applications of various mathematical concepts used in this sector/ industry.

GUIDELINES: [IN PROCESS]

Topic Selection and Proposal:

- Choose a well-defined and feasible topic that aligns with your interests, available resources, and the expertise of your mentors.
- Develop a clear and comprehensive project proposal that outlines the research objectives, significance, methodology, and expected outcomes.

Research Planning:

- Define your research question and objectives precisely. Identify the scope of your study, study area within Maharashtra, and the timeline for fieldwork.
- Conduct a thorough literature review to understand the existing knowledge and identify gaps in the chosen area of study.

Methodology:

- Determine the appropriate research methods and techniques based on your research objectives. These might include field surveys, sample collection, laboratory analysis, interviews, or experiments.
- Detail the step-by-step procedures you will follow during fieldwork, ensuring they are well-structured and repeatable.

Ethics and Permissions:

- If your research involves human subjects, ensure you obtain necessary ethical approvals from your academic institution.
- If conducting research/field work in protected areas or involving sensitive species, obtain required permits or approvals from relevant authorities.

Data Collection:

- Collect data systematically and accurately according to your defined methodology. Maintain organized records of observations, samples, measurements, and any other relevant information.

Data Analysis:

- Organize and manage your collected data in a format suitable for analysis.
- Apply appropriate statistical or analytical techniques to interpret your data and draw meaningful conclusions.

Results and Interpretation:

- Present your findings using tables, graphs, charts, and descriptive text.

- Interpret your results in the context of your research question and compare them with existing literature.

Discussion and Conclusion:

- Discuss the implications of your findings, considering how they contribute to the existing knowledge in your field and address the research gaps you identified.
- Reflect on any limitations of your study and suggest potential avenues for further research.

Reporting and Documentation:

- Create a well-structured report that includes an introduction, objectives, methods, results, discussion, and conclusion sections.
- Include proper citations for references to literature.
- Visual aids such as photographs, maps, and diagrams can enhance the clarity of your report.

Presentation and Communication:

- Present your findings to your academic institution, peers, and mentors through a seminar, presentation, or poster session.
- Practice clear and concise communication to effectively convey your research process and outcomes.

Time Management:

- Plan your fieldwork, data collection, and analysis schedule to ensure efficient use of time and resources.

Mentorship and Feedback:

- Collaborate closely with mentors or advisors who can provide guidance, feedback, and support throughout the project.

Flexibility and Adaptability:

- Be prepared to adjust your plans if you encounter unexpected challenges during fieldwork or analysis.

LEARNING RESOURCE DETAILS

LRCode	Title Author	EditionYear	ISBN Publisher
CourseWebsiteLinkfor(1)MobileandOnlineLectures,(2)DiscussionForumforonlineinteractionand(3)SelfTestforeachCRBlock,ContinuousAssessmentTestandEndExamination			
Text-Books			
MAT506-T01	Operations Research, Dr. Subhash G. Pawar& Ms. Chetana V. Visave	2021	978-93-92982-16-3 YCMOU
MAT507-T01	Numerical Analysis Dr. MeenakshiWasadikar& Dr. S. K. Nimbhorkar	2020	978-93-91514-54-9 YCMOU
MAT503-	Ordinary Differential Equations	2021	978-93-91514-52-5

T01	Dr. H.L. Tidke& Dr. L. N. Katkar		YCMOU
Reference-Books: Explore additional details and reinforce learning, with this optional learning resource!			
MAT514 – RB1			
CD / DVD: Explore additional details and reinforce learning, with this optional learning resource!			
MAT514 - CD1			
Web Links: Explore additional details and reinforce learning, with this optional learning resource!			
MAT514- WL1			

COURSE OUTCOMES

After successful completion of this course, student should be able to –

- Demonstrate the ability to apply advanced mathematical theories, methods, and techniques to solve real-world problems in diverse fields such as engineering, finance, physics, computer science, or biology.
- Develop proficiency in conducting independent research, including literature review, problem formulation, hypothesis testing, data collection, analysis, and interpretation within their chosen field of study.
- Enhance their analytical skills by critically evaluating mathematical models, algorithms, and computational techniques, identifying limitations, and proposing innovative solutions or improvements.
- Gain hands-on experience with relevant software tools, programming languages, and computational methods commonly used in applied mathematics and related disciplines.
- Communicate their research findings, methodologies, and conclusions through written reports, presentations, and oral discussions, catering to both technical and non-technical audiences.
- Collaborate with peers, advisors, industry partners, or stakeholders to define project objectives, allocate responsibilities, share insights, and integrate diverse perspectives into the project's development and implementation.
- Acquire project management skills, including planning, scheduling, budgeting, and risk management, to ensure the successful execution and completion of the field project within specified timelines and resource constraints.

ELECTIVE COURSES

MAT515: NUMBER THEORY

PROGRAMME INFORMATION

SN	Description	Details
1	University	Yashwantrao Chavan Maharashtra Open University Nashik - 422 222, Maharashtra, India Website: http://www.ycmou.ac.in/and http://ycmou.digitaluniversity.ac/
2	School	School of Sciences
3	Discipline	Science
4	Level	PG
5	Course Used in	V151: M.Sc.(Mathematics) {2023 Pattern} & V130 M.Sc.(Mathematics){2021 Pattern}

COURSE INFORMATION

Sem	Major	Code	Course Name	CR	CST	ST	CA	EE	TM	Type
02	DSE	MAT515	Number Theory	4	12	120	30	70	100	T

PRESUMED KNOWLEDGE AND LEARNING OBJECTIVES

Presumed Knowledge	Learning Objectives
For successful completion of this course, student should have successfully complete: • BSc/BA with Mathematics or equivalent from a recognized University/Board.	The objectives of this course are • To study Fundamental Theorem of Arithmetic ,Euclidean Algorithm • To introduce Arithmetic factions λ, σ_α • To explain concept of Congruences • To study Chinese Remainder Theorem

UNITS

UN	Name of the Unit	CSs	Questions
01-01 01-02 01-03 01-04	**The Fundamental Theorem of Arithmetic** **The Euclidean Algorithm** **Arithmetic Functionsμ and ϕ** **Arithmetic Functions and Dirichlet Product**	**CR 01**	As per evaluation pattern, on Each Credit, Student is required to answer • Very Short Answer Question (VSAQ), of 03 marks • Short Answer Question (SAQ), of 05 marks • Long Answer Question (LAQ) of 10 Marks (LAQ may contain sub-questions (a), (b) and so on.)
02-01 02-02 02-03 02-04	**Arithmetic Functions λ and σ_α** **Formal power series** **Congruences** **Polynomial Congruences**	**CR 02**	
03-01 03-02 03-03 03-04	**The Chinese Remainder Theorem** **Diophantine Equations** **Quadratic Residues** **Quadratic Reciprocity law**	**CR 03**	
04-01 04-02 04-03 04-04	**Jacobi Symbol** **Primitive roots** **Existence of Primitive Roots** **The Index Calculus**	**CR 04**	

DETAILED SYLLABUS

UN	Detailed Syllabus of the Unit	CR
1-1	**The Fundamental Theorem of Arithmetic**: Divisibility, Greatest common divisor, Prime numbers, The fundamental theorem of arithmetic.	
1-2	**The Euclidean Algorithm**: The series of reciprocals of the primes, The Euclidean algorithm, The greatest common divisor of more than two numbers.	
1-3	**Arithmetic Functions $\mu$and ϕ**: The Mobius function $\mu(n)$,The Euler totient function $\phi(n)$, A relation connecting $\mu(n)$and $\phi(n)$, A product formula for $\phi(n)$.	**CR 01**
1-4	**Arithmetic Functions and Dirichlet Product:** The Dirichlet product of arithmetical functions, Dirichlet inverses and the Mobius inversion formula, The Mangoldt function $\Lambda(n)$, Multiplicative functions, Multiplicative functions and Dirichlet multiplication, The inverse of a completely multiplicative function.	
2-1	**Arithmetic Functionsλ and σ_α:**Liouville's function $\lambda(n)$, The divisor functions $\sigma_\alpha(n)$, Generalized convolutions.	
2-2	**Formal power series:** The Bell series of an arithmetical function, Bell series and Dirichlet multiplication, Derivatives of arithmetical functions, The Selberg identity.	**CR 02**
2-3	**Congruences:** Definition and basic properties of congruences, Residue classes and complete residue systems, Linear congruences.	
2-4	**Polynomial Congruences:** Reduced residue systems and the Euler-Fermat theorem, Polynomial congruences module p. Lagrange's theorem, Applications of Lagrange's theorem.	
3-1	**The Chinese remainder theorem**: Simultaneous linear congruences, Applications of the Chinese remainder theorem, Polynomial congruences with prime power moduli.	
3-2	**Diophantine Equations:** Diophantine equations, Finite continued fractions, Solutions of Diophantine equations by using finite simple continued fractions.	**CR 03**
3-3	**Quadratic Residues:** Quadratic residues, Legendre's symbol and its properties, Evaluation of $(-1/p)$ and $(2/p)$,	
3-4	**Quadratic Reciprocity law:** Gauss' lemma, The quadratic reciprocity law, Applications of the reciprocity law.	
4-1	**Jacobi Symbol**: The Jacobi symbol, Applications to Diophantine equations.	
4-2	**Primitive roots:** The exponent of a number $mod\ m$. Primitive roots and reduced residue systems, The nonexistence of primitive roots mod $2^\alpha$for $\alpha \geq 3$, The existence of primitive roots $mod\ p$ for odd primes p.	**CR 04**
4-3	**Existence of Primitive Roots**: Primitive roots and quadratic residues, The existence of primitive roots p^α , The existence of primitive roots $mod\ 2p^\alpha$, The nonexistence of primitive roots in the remaining cases, The number of primitive roots $mod\ m$.	
4-4	**The index calculus:** Index with respect to primitive roots, Examples	

LEARNING RESOURCE DETAILS

LR Code	Title Author	Edition Year	ISBN Publisher

Course Website Link for (1) Mobile and Online Lectures, (2) Discussion Forum for online interaction and (3) Self-Test for each CR Block, Continuous Assessment Test and End Examination			
CW-MAT515			
Text-Books			
MAT515-T01	Number Theory, Dr. J. N. Chaudhari & Dr. K. J. Ingale	2020	978-93-91514-61-7 YCMOU
Reference-Books: Explore additional details and reinforce learning, with this optional learning resource!			
MAT515 – RB1	Introduction to Analytic Number Theory, Tom M. Apostol	1976	Springer-Verlag NY Heidelberg Berlin
MAT515 – RB2	Elementary Number Theory, Burton D M	2nd, 2003	Universal Book Stall, New Delhi
MAT515 – RB3	Elementary Theory of Numbers, Hsiung C Y,	1992	Allied Publishers Ltd
MAT515 – RB4	Elementary Number Theory, Jones Gareth A and Jones J Mary	2005	Springer,
MAT515 – RB5	Elementary Number Theory, Karade T M, J N Salunke and Bendre M S,	2018	Sonu-Nilu
MAT515 – RB6	Elementary Number theory with Applications, Koshy Thomas,	2002	Academic Press
MAT515 – RB7	An Introduction to the Theory of Numbers, Niven I, Zuckerman H S and Montgomery H L	5th, 2004	Wiley Student Edition
MAT515 – RB8	Elementary Number Theory and its Applications, Rosen K H	1986	Addison-Wesley
CD / DVD: Explore additional details and reinforce learning, with this optional learning resource!			
MAT515 - CD1			
Web Links: Explore additional details and reinforce learning, with this optional learning resource!			
MAT515-WL1			

COURSE OUTCOMES

After successful completion of this course, student should be able to

- Understand the concept of arithmetical functions
- Solve problems based on congruences and quadratic residues
- Know the concepts of primitive root theory

MAT516: Field Theory

Programme Information

SN	Description	Details
1	University	Yashwantrao Chavan Maharashtra Open University Nashik - 422 222, Maharashtra, India Website: http://www.ycmou.ac.in/and http://ycmou.digitaluniversity.ac/
2	School	School of Sciences
3	Discipline	Science
4	Level	PG
5	Course Used in	V151: M.Sc.(Mathematics) {2023 Pattern} & V130 M.Sc.(Mathematics){2021 Pattern}

Course Information

Sem	Major	Code	Course Name	CR	CST	ST	CA	EE	TM	Type
02	DSE	MAT516	Field Theory	4	12	120	30	70	100	T

Presumed Knowledge and Learning Objectives

Presumed Knowledge	Learning Objectives
For successful completion of this course, student should have successfully complete: • BSc/BA with Mathematics or equivalent from a recognized University/Board.	The objectives of this course are • To explain the concepts in field theory such as finite and algebraic extensions, algebraic elements, constructible elements, solvable groups etc • To Elaborate notions in finite field theory and their applications.

Units

UN	Name of the Unit	CSs	Questions
01-01 01-02 01-03 01-04	**Irreducible Polynomials** **Adjunction of Roots** **Algebraic Extensions** **Algebraically Closed Fields**	CR 01	As per evaluation pattern, on Each Credit, Student is required to answer • Very Short Answer Question (VSAQ), of 03 marks • Short Answer Question (SAQ), of 05 marks • Long Answer Question (LAQ) of 10 Marks (LAQ may contain sub-questions (a), (b) and so on.)
02-01 02-02 02-03 02-04	**Splitting Fields** **Simple Extensions** **Finite Fields** **Separable Extensions**	CR 02	
03-01 03-02 03-03 03-04	**Automorphism Groups** **NormalExtensions** **Fundamental Theorem of Galois Theory** **Different Galois Groups**	CR 03	
04-01 04-02 04-03 04-04	**Cyclotomic Polynomials** **Cylic Extensions** **Polynomials Solvable by Radicals** **Ruler and Compass Constructions**	CR 04	

Detailed Syllabus

UN	Detailed Syllabus of the Unit	CR
1-1	**Irreducible Polynomials**: Ring Homomorphism, Ideals in a Ring, Definition	CR

	and properties of irreducible polynomials	**01**
1-2	**Adjunction of Roots**: Field and its properties, Field extension, Field Adjunction	
1-3	**Algebraic Extension**: Algebraic extension, Relation between finite and algebraic extensions	
1-4	**Algebraically Closed Fields:** Root of Polynomial over field, Definition and equivalent forms of algebraically closed field, algebraic closure, and existence of algebraically closed field	
2-1	**Splitting Fields:** Existence of Splitting field, Splitting field of polynomial	**CR 02**
2-2	**Simple Extensions:** Definition, Theorems on simple extension	
2-3	**Finite Fields:** Definition, Theorems, Existence & Uniqueness of finite fields, construction of finite fields, subfield and primitive roots, Spilling Field over finite fields	
2-4	**Separable Extensions:** Separable polynomial, separable extension, perfect field, simple extension and their properties, transitivity of finite separable extensions.	
3-1	**Automorphism Groups:** Definition of group of automorphism with examples, Galois group of extension	**CR 03**
3-2	**Normal Extensions:** Definition and Example, isomorphism & Normal extension	
3-3	**Fundamental Theorem of Galois Theory:** Galois group, Galois extension, Order of Galois group of extension, Group Action, Theorem on symmetric polynomials, Fundamental Theorem of Galois Theory	
3-4	**Different Galois Groups:** Galois group of a polynomial of different degrees, Galois group of a polynomial of order 2 and 3	
4-1	**Cyclotomic Polynomials:** Cyclotomic Field ,Cyclotomic polynomials	**CR 04**
4-2	**CylicExtensions:** Definition and examples of cyclic extensions, Frobeniusautomorphism	
4-3	**Polynomials Solvable by Radicals:** Radical extension, polynomial solvable by radicals and its properties, Examples of polynomials solvable by radicals.	
4-4	**Ruler and Compass Constructions:** Constructible points, lines and circles, Field of constructible numbers, constructible numbers , Impossibility of certain constructions	

LEARNING RESOURCE DETAILS

LR Code	Title Author	Edition Year	ISBN Publisher
Course Website Link for (1) Mobile and Online Lectures, (2) Discussion Forum for online interaction and (3) Self-Test for each CR Block, Continuous Assessment Test and End Examination			
CW-MAT516			
Text-Books			
MAT516-T01	Field Theory Prof. S. R. Chaudhari	2021	978-93-92982-57-6 YCMOU
Reference-Books: Explore additional details and reinforce learning, with this optional learning resource!			
MAT516 –	Basic Abstract Algebra,	2nd	Cambridge

RB1	P.B. Bhattacharya, S.K. Jain, S.R. Nagpaul,	Edition	University Press
MAT516 – RB2	Abstract Algebra, D.S. Dummit and R. M. Foote,	2nd Edition	John Wiley, 2002.
MAT516 – RB3	Galois Theory, Joseph Rotman	2nd Edition	Springer International Edition
MAT516 – RB4	Basic Algebra I, N. Jacobson	2nd Edition	Hindustan Publishing Co., 1984.
MAT516 – RB5	Algebra I, S. Lang	3rd Ed 2005	Addison Wesley,
MAT516 – RB6	Topics in Algebra, I N Herstein	2nd Ed	John Wiley
CD / DVD: Explore additional details and reinforce learning, with this optional learning resource!			
MAT516 - CD1			
Web Links: Explore additional details and reinforce learning, with this optional learning resource!			
MAT516-WL1			

COURSE OUTCOMES

After successful completion of this course, student should be able to

- Understand concepts in field theory such as finite and algebraic extensions, algebraic elements, constructible elements, solvable groups etc
- Aware the motive behind development of galois theory and solvability by radicals
- Apply concepts in field theory for solving polynomial equations, systems of equations, ancient problems on impossibility of constructions and finding formula for solutions of polynomial equations.

SEMESTER 03

MAT601: COMPLEX ANALYSIS

PROGRAMME INFORMATION

SN	Description	Details
1	University	Yashwantrao Chavan Maharashtra Open University Nashik - 422 222, Maharashtra, India Website: http://www.ycmou.ac.in/and http://ycmou.digitaluniversity.ac/
2	School	School of Sciences
3	Discipline	Science
4	Level	PG
5	Course Used in	V151: M.Sc.(Mathematics) {2023 Pattern} & V130 M.Sc.(Mathematics){2021 Pattern}

COURSE INFORMATION

Sem	Major	Code	Course Name	CR	CST	ST	CA	EE	TM	Type
03	DSC	MAT601	Complex Analysis	4	12	120	30	70	100	T

PRESUMED KNOWLEDGE AND LEARNING OBJECTIVES

Presumed Knowledge	Learning Objectives
For successful completion of this course, student should have successfully complete: • BSc/BA with Mathematics or equivalent from a recognized University/Board.	The objectives of this course are • To develop the concepts of analytic functions, harmonic functions and the importance of the Cauchy Riemann equations. • To study how to solve integration of function by using analyticity • To explore basic properties of singularities zeros residues, poles to solve integrals. • To illustrate the application of Hadamard Theorem and Uniqueness of Direct Analytic Continuation along a Curve, Power Series Method of Analytic Continuation

UNITS

UN	Name of the Unit	CSs	Questions
01-01 01-02 01-03 01-04	**Power Series** **Analytic Functions** **Harmonic Functions** **Mobius Transformations**	**CR 01**	As per evaluation pattern, on Each Credit, Student is required to answer • Very Short Answer Question (VSAQ), of 03 marks • Short Answer Question (SAQ), of 05 marks • Long Answer Question (LAQ) of 10 Marks (LAQ may contain sub-questions (a), (b) and so on.)
02-01 02-02 02-03 02-04	**Power Series Analytic of Analytic Functions** **Zeros of Analytic Functions** **The Index of a Closed Curve** **Morera's Theorem and Counting Zeros**	**CR 02**	
03-01 03-02 03-03 03-04	**Goursat's Theorem** **Classification of Singularities** **Residues** **The Argument Principle**	**CR 03**	

04-01 04-02 04-03 04-04	**Branches** **Hadamard Theorem** **Spaces** **Analytic Continuation**	**CR 04**	

DETAILED SYLLABUS

UN	Detailed Syllabus of the Unit	CR
1-1	**Power Series**: Definition of power series, convergence, absolute convergence, Radius of convergence.	**CR 01**
1-2	**Analytic Functions**: Definition, Properties of analytic function, Periodic function, Branch of the logarithm, C-R equations, Harmonic conjugate.	
1-3	**Harmonic Function:** Definition, properties, Harmonic conjugate.	
1-4	**Mobius Transformations**: Mobius transformations, Path, Properties of path, Cross ratio, Orientation Principle.	
2-1	**Power Series Representation of Analytic Functions**: Leibniz's rule, Cauchy's Integral formula, Taylor's theorem, Cauchy's Estimate.	
2-2	**Zeros of an Analytic Function**: Zero of analytic function, Entire function, Liouville's theorem, Fundamental Theorem of Algebra, Identity theorem, Maximum Modulus theorem.	
2-3	**The Index of a Closed Curve and Cauchy's Theorem and Integral Formula**: Winding number, Cauchy's Integral Formula, Cauchy's theorem	
2-4	**Morera's Theorem and Counting Zeros**: Morera's Theorem, Counting zeros, The open mapping theorem.	
3-1	**Goursat's Theorem**: Goursat's theorem, The Maximum Principle, Schwarz's Lemma	**CR 03**
3-2	**Classification of Singularities**: Isolated singularity, removable singularity, pole, Laurent Series Development, Casorati-Weierstrass Theorem	
3-3	**Residues**: Residue Theorem, Contour integrations	
3-4	**The Argument Principle**: Meromorphic function, holomorphic function, Rouche's Theorem	
4-1	**Branches:** Branches of many valued Functions (Specially argz, logz, z^{alpha})	**CR 04**
4-2	**Hadamard Theorem**: Hadamard's three Circle Theorem, Phragmen-Lindel of theorem	
4-3	**Spaces** : Spaces and Continuous Functions, Spaces of Analytic functions, Hurmitz Theorem	
4-4	**Analytic Continuation**: Analytic Continuation, Uniqueness of Direct Analytic Continuation, Uniqueness of Direct Analytic Continuation along a Curve, Power Series Method of Analytic Continuation	

LEARNING RESOURCE DETAILS

LR Code	Title Author	Edition Year	ISBN Publisher
Course Website Link for (1) Mobile and Online Lectures, (2) Discussion Forum for online interaction and (3) Self-Test for each CR Block, Continuous Assessment Test and End Examination			
CW-MAT601			

Text-Books			
MAT601-T01	Complex Analysis Dr. C. T. Aage and Dr. Kishor D. Kucche	2022	978-93-95855-32-7 YCMOU
Reference-Books: Explore additional details and reinforce learning, with this optional learning resource!			
MAT601 – RB1	Functions of one Complex Variable, John B. Conway	2002	81-85015-37-6 Narosa Publishing House
MAT601 – RB2	Complex Variables with Applications, Saminathan Ponnusamy, Herb Silverman	2006	10: 0-8176-4457-1 Birkhauser Boston
MAT601 – RB3	Complex Analysis, Theodore W. Gamelin	2003	978-0387950693 Springer
MAT601 – RB4	Complex Variables and Applications, R V Churchill and J W Brown	8th Ed	MC Graw Hill
CD / DVD: Explore additional details and reinforce learning, with this optional learning resource!			
MAT601 - CD1			
Web Links: Explore additional details and reinforce learning, with this optional learning resource!			
MAT601-WL1			

COURSE OUTCOMES

After successful completion of this course, student should be able to

- Understand the concepts of analytic functions, harmonic functions and the importance of the Cauchy Riemann equations.
- Apply analyticity solve integration of functions
- Describe the basic properties of singularities, zeros residues, poles to solve integrals.
- Apply concept of Hadamard Theorem and Uniqueness of Direct Analytic Continuation along a Curve, Power Series Method of Analytic Continuation

MAT602: Measure and Integration Theory

Programme Information

SN	Description	Details
1	University	Yashwantrao Chavan Maharashtra Open University Nashik - 422 222, Maharashtra, India Website: http://www.ycmou.ac.in/and http://ycmou.digitaluniversity.ac/
2	School	School of Sciences
3	Discipline	Science
4	Level	PG
5	Course Used in	V151: M.Sc.(Mathematics) {2023 Pattern} & V130 M.Sc.(Mathematics){2021 Pattern}

Course Information

Sem	Major	Code	Course Name	CR	CST	ST	CA	EE	TM	Type
03	DSC	MAT602	Measure and Integration Theory	4	12	120	30	70	100	T

Presumed Knowledge and Learning Objectives

Presumed Knowledge	Learning Objectives
For successful completion of this course, student should have successfully complete: • BSc/BA with Mathematics or equivalent from a recognized University/Board.	The objectives of this course are • To introduce the concept of Lebesgue Measure & properties of measurable sets • To explain measurable function & its properties • To study the Integration of Bounded Measurable Functions& its properties • To explain L^p Spaces, Riesz Theorem

Units

UN	Name of the Unit	CSs	Questions
01-01 01-02 01-03 01-04	**Lebesgue Measure** **The Algebra of Lebesgue Measure** **The Approximate Measurable sets** **Additivity of Measurable sets**	**CR 01**	As per evaluation pattern, on Each Credit, Student is required to answer • Very Short Answer Question (VSAQ), of 03 marks • Short Answer Question (SAQ), of 05 marks • Long Answer Question (LAQ) of 10 Marks (LAQ may contain sub-questions (a), (b) and so on.)
02-01 02-02 02-03 02-04	**Measurable Functions** **Algebra of Measurable functions** **Sequential Point-wise Limits and Simple Approximation** **Littlewood's Three Principles**	**CR 02**	
03-01 03-02 03-03 03-04	**Integration of Bounded Measurable Functions** **General Lebesgue Integration** **Countable Additivity and Continuity of Integration** **Lebesgue Integration Further Topics**	**CR 03**	

04-01 04-02 04-03 04-04	**Differentiation and Integration** **Functions of Bounded Variations** **The L^p Spaces** **The Riesz Theorem**	**CR 04**	

DETAILED SYLLABUS

UN	Detailed Syllabus of the Unit	CR
1-1	**Lebesgue Measure:** Lebesgue measure, Outer Measure, Measurable sets.	CR 01
1-2	**The σ-Algebra of Lebesgue Measurable Sets:** Union, intersection, complementation of measurable sets, countable union of measurable sets, measurability of intervals.	
1-3	**Approximate measurable sets**: Outer and Inner Approximation of Lebesgue Measurable Sets.	
1-4	**Additivity of measurable sets:** Countable Additivity, Continuity of measure, The Borel-Cantelli Lemma, Non-measurable sets, The Cantor Set and the Cantor-Lebesgue.	
2-1	**Measurable Functions**: Measurability of function, equivalent conditions for measurability.	CR 02
2-2	**Algebra of measurable functions:** Sums, Products, and Composition of measurable functions.	
2.3	**Sequential Pointwise Limits and Simple Approximation:** Theorems on sequential limits.	
2.4	**Littlewood's Three Principles:** Three principles, Egoroffs Theorem, and Lusin's Theorem.	
3-1	**Integration of Bounded Measurable Functions:** The Riemann Integral, The Lebesgue Integral of a Bounded Measurable Function over a Set of Finite Measure, Linearity and Monotonicity of Integration, The Bounded Convergence Theorem.	CR 03
3-2	**General LebesgueIntegration:** The Lebesgue Integral of a Measurable Nonnegative Function, The Monotone Convergence Theorem, The General Lebesgue Integral, The Lebesgue Dominated Convergence Theorem.	
3.3	**Countable Additivity and Continuity of Integration:** The Vitali Convergence theorem, uniformly integrable functions,	
3.4	**Lebesgue Integration Further Topics:** Uniform Integrability, General Vitali Convergence Theorem, Convergence in Measure, Characterizations of Riemann and Lebesgue Integrability, Lebesgue Theorem.	
4-1	**Differentiation and Integration:** Continuity of Monotone Functions, Differentiability of Monotone Functions: Lebesgue's Theorem	CR 04
4-2	**Functions of Bounded Variations:** Bounded and total variations, Jordan Decomposition, Continuous Functions	
4-3	**The L^p Spaces:** Normed Linear Spaces, The Inequalities of Young, Holder, and Minkowski's inequality.	
4-4	**Riesz Theorem**: Banach Space, Riesz-Fisher theorem, Approximation and Separability, The Riesz Representation Theorem.	

LEARNING RESOURCE DETAILS

LR Code	Title Author	Edition Year	ISBN Publisher
Course Website Link for (1) Mobile and Online Lectures, (2) Discussion Forum			

for online interaction and (3) Self-Test for each CR Block, Continuous Assessment Test and End Examination			
CW-MAT602			
Text-Books			
MAT602-T01	Measure and Integration Theory, Dr. S. R. Chaudhari	2020	978-93-91514-55-6 YCMOU
Reference-Books: Explore additional details and reinforce learning, with this optional learning resource!			
MAT602 – RB1	Real Analysis, H. L. Royden and P. M. Fitzpatrick	4th, 2010	Pearson Education Asia China Machine press.
MAT602 – RB2	Real Analysis, H. L. Royden	2nd , 1968	The MacMillan Company New York
MAT602 – RB3	Lebesgue Measure and Integration, P.K. Jain and V. P. Gupta	1986	John Willey and Sons, New York
CD / DVD: Explore additional details and reinforce learning, with this optional learning resource!			
MAT602 - CD1			
Web Links: Explore additional details and reinforce learning, with this optional learning resource!			
MAT602-WL1			

COURSE OUTCOMES

After successful completion of this course, student should be able to

- Develop fundamentals of measurable sets and functions
- Apply the concept of measurability of function and sets to solve integration of functions.
- Discuss L^p spaces in more general setting and use them to prove Riesz theorem.

MAT603: INTEGRAL EQUATIONS

PROGRAMME INFORMATION

SN	Description	Details
1	University	Yashwantrao Chavan Maharashtra Open University Nashik - 422 222, Maharashtra, India Website: http://www.ycmou.ac.in/and http://ycmou.digitaluniversity.ac/
2	School	School of Sciences
3	Discipline	Science
4	Level	PG
5	Course Used in	V151: M.Sc.(Mathematics) {2023 Pattern} & V130 M.Sc.(Mathematics){2021 Pattern}

COURSE INFORMATION

Sem	Major	Code	Course Name	CR	CST	ST	CA	EE	TM	Type
03	DSC	MAT603	Integral Equations	2	6	60	15	35	50	T

PRESUMED KNOWLEDGE AND LEARNING OBJECTIVES

Presumed Knowledge	Learning Objectives
For successful completion of this course, student should have successfully complete: • BSc/BA with Mathematics or equivalent from a recognized University/Board.	The objectives of this course are • To introduce integral equations & explain method of Successive Approximation • To study Dirac Delta function Green's function

UNITS

UN	Name of the Unit	CSs	Questions
01-01 01-02 01-03 01-04	**Introduction** **Integral Equation with Separable Kernel** **Method of Successive Approximation** **Resolvent Kernel**	**CR 01**	As per evaluation pattern, on Each Credit, Student is required to answer • Very Short Answer Question (VSAQ), of 03 marks • Short Answer Question (SAQ), of 05 marks • Long Answer Question (LAQ) of 10 Marks (LAQ may contain sub-questions (a), (b) and so on.)
02-01 02-02 02-03 02-04	**Application to Ordinary Differential Equations** **Dirac Delta function** **Green's function** **Modified Green's function**	**CR 02**	

DETAILED SYLLABUS

UN	Detailed Syllabus of the Unit	CR
1-1	**Introduction:** Regularity Conditions, Special kinds of kernels, Eigen values and Eigen functions	**CR 01**
1-2	**Integral equation with Separable Kernel:** Convolution integral, Reduction to a system of algebraic equations, Fredholm alternative	
1-3	**Method of Successive Approximation**: An approximate method, Iterative scheme, Volterra integral equation	
1-4	**Resolvent Kernel**: Some results about the Resolvent kernel	

2-1	**Application to Ordinary Differential Equations:** Initial value problems, Boundary value problems	**CR 02**
2-2	**Dirac Delta function:** Adjoint equation of second order linear equation and self adjoint equation, Dirac delta function	
2-3	**Green's Function**: Green's function approach, Green's function for Nth–order ordinary differential equation	
2-4	**Modified Green's Function:** Modified Green's function	

LEARNING RESOURCE DETAILS

LR Code	Title Author	Edition Year	ISBN Publisher
Course Website Link for (1) Mobile and Online Lectures, (2) Discussion Forum for online interaction and (3) Self-Test for each CR Block, Continuous Assessment Test and End Examination			
CW-MAT603			
Text-Books			
MAT603-T01	Integral Equations, Dr. D. D. Pawar		978-93-92982-01- 9 YCMOU
Reference-Books: Explore additional details and reinforce learning, with this optional learning resource!			
MAT603 – RB1	Linear Integral Equations, R. P. Kanwal	1971	Academic Press
MAT603 – RB2	Integral Equations, S. G. Mikhlin	1957	PergamonPress
MAT603 – RB3	A first Course in Integral Equations, A. M. Wazwaz	1997	World Scientific
MAT603 – RB4	The Analysis of Linear Integral Equations, J. A. Cochran	1972	MC-Graw Hill
MAT603 – RB5	Problems and Exercises in Integral Equations, M. A. Krasnow, Kislov and G. Hakaronke	1971	MIR Pub.
MAT603 – RB6	Integral Equations: A short Course, Li, G Chambers	1976	International Textbook company
CD / DVD: Explore additional details and reinforce learning, with this optional learning resource!			
MAT603 - CD1			
Web Links: Explore additional details and reinforce learning, with this optional learning resource!			
MAT603-WL1			

COURSE OUTCOMES

After successful completion of this course, student should be able to

- Classify and solve integral equations
- Apply integral equations to solve ODEs

MAT604: MATHEMATICAL STATISTICS & COMBINATORICS

PROGRAMME INFORMATION

SN	Description	Details
1	University	Yashwantrao Chavan Maharashtra Open University Nashik - 422 222, Maharashtra, India Website: http://www.ycmou.ac.in/and http://ycmou.digitaluniversity.ac/
2	School	School of Sciences
3	Discipline	Science
4	Level	PG
5	Course Used in	V151: M.Sc.(Mathematics) {2023 Pattern}

COURSE INFORMATION

Sem	Major	Code	Course Name	CR	CST	ST	CA	EE	TM	Type
03	DSC	MAT604	Mathematical Statistics & Combinatorics	4	12	120	50	50	100	P

PRESUMED KNOWLEDGE AND LEARNING OBJECTIVES

Presumed Knowledge	Learning Objectives
For successful completion of this course, student should have successfully complete: • BSc/BA with Mathematics or equivalent from a recognized University/Board.	The objectives of this course are • To acquaint students with basic concepts in statistics • To study various graphical and diagrammatic techniques of data representation • To explore various measures of central tendency, dispersion, skewness and kurtosis. • To explain correlation coefficient from ungrouped bivariate data and interpret • them. • To apply concept of permutation and combination • To introduce to the basic concepts of probability, axiomatic theory of probability, concept of random variable, probability distribution

Note: (1) The theoretical background relevant to the experiments listed below should be discussed during practical sessions only.
(2) Wherever possible, the output should be presented in graphical form also.

LAB ACTIVITY

SN	Title of Activity	CR
1	To represent given data diagrammatically: simple and subdivided bar diagrams, multiple bar diagram, percentage bar diagram, pie diagram also by using Excel	CR 01
2	To represent given data graphically: Histogram, frequency curve and ogive curves also by using Excel	

3	To compute measures of central tendency and dispersion (ungrouped data) also by using Excel	
4	To compute measures of central tendency and dispersion (grouped data) also by using Excel	
5	To calculate Moments, Coefficient of Skewness, Kurtosis	**CR 02**
6	To calculate Correlation Coefficient	
7	To fit Regression line for bivariate data	
8	Scatter diagram, correlation coefficient, fitting of a line of regression, fitting of second degree curve using Ms-excel	
9	To apply basic counting Principles: Addition Principle and Multiplication Principle	**CR 03**
10	To calculate number of possible ways of Arrangements with Repetition (Permutation)	
11	To calculate number of possible ways of Selections with Repetition (Combination)	
12	To apply Classical definition of probability	
13	To apply Axiomatic definition of probability	
14	To apply Conditional Probability and Bayes' Theorem	
15	To apply Binomial & Hypergeometric distributions	**CR 04**
16	To apply Poisson & Geometric distributions	
17	To apply Normal Distribution	
18	To calculate probability of Binomial, Hypergeometric, Poisson, Geometric, Normal distribution by using Ms-excel	

LEARNING RESOURCE DETAILS

LR Code	Title Author	Edition Year	ISBN Publisher
Text-Books			
Reference-Books: Explore additional details and reinforce learning, with this optional learning resource!			
MAT 604 - RB1	Fundamentals of Mathematical Statistics, Gupta, S. C. and Kapoor, V. K.	Eighth Edition, 1983	Sultan Chand and Sons Publishers, New Delhi.
MAT 604 – RB2	Fundamentals of Applied Statistics, Gupta, S. C. and Kapoor, V. K.	Third Edition, 1997	Sultan Chand and Sons Publishers, New Delhi.
MAT 604 – RB3	Fundamentals of Statistics, Goon, A. M., Gupta, M. K. and Dasgupta, B.	Sixth Revised Edition, 1983	The World Press Pvt. Ltd., Calcutta.
MAT 604 – RB4	Introductory Statistics, Neil A. Weiss	Tenth Edition 2016	Pearson
MAT 604 – RB5	Applied Combinatorics, Alan Tucker	6th Edition	John Wiley & Sons, Inc.

		2012	
V137 – DSS014	Excel Applications in Statistics, Tejaswi Kadam		Pub. No. 2492 YCMOU
CD / DVD: Explore additional details and reinforce learning, with this optional learning resource!			
-CD1			
Web Links: Explore additional details and reinforce learning, with this optional learning resource!			
MAT 604 – WL1	DSS014_ Excel Application in Statistics - Google Drive		

COURSE OUTCOMES

After successful completion of this course, student should be able to

- Use various graphical and diagrammatic techniques of data representation
- Analyse data pertaining to discrete and continuous variables and to interpret the results
- Compute various measures of central tendency, dispersion, skewness and kurtosis
- Summarize and analyze the data using computer
- Find the probabilities of events
- Apply standard probability distributions to different situations

MAT605: RESEARCH PROJECT

PROGRAMME INFORMATION

SN	Description	Details
1	University	Yashwantrao Chavan Maharashtra Open University Nashik - 422 222, Maharashtra, India Website: http://www.ycmou.ac.in/and http://ycmou.digitaluniversity.ac/
2	School	School of Sciences
3	Discipline	Science
4	Level	PG
5	Course Used in	V151: M.Sc.(Mathematics) {2023 Pattern}

COURSE INFORMATION

Sem	Other Course	Code	Course Name	CR	CST	ST	CA	EE	TM	Type
03	RP	MAT605	Research Project	4	12	120	50	50	100	PW

PRESUMED KNOWLEDGE AND LEARNING OBJECTIVES

Presumed Knowledge	Learning Objectives
For successful completion of this course, student should have successfully complete: • BSc/BA with Mathematics or equivalent from a recognized University/Board.	The objectives of this course are • To gain expertise in Research Design and Methodology • To acquire skills in collecting and analyzing data • To learn effective time management and project planning skills • To develop problem-solving skills and the ability to adapt research strategies

GUIDELINES:

No	Guidelines for the Students and Study Centers for the conduct of Project
1	The "Project Work" course aims to imbibe in students the principle that working is learning. Learning and working are two sides of the same coin and thus, work experience enhances the learning.
2	This course is based on preliminary research oriented topics both in theory and experiment. The subject expert/ counsellor will act as supervisors for the projects. Project shall be on the current and relevant topics and issues. Project topic is jointly finalized by the student and the project supervisors through discussion. At the completion of the project by the semester end, the student will submit a Project Report in the form of Dissertation which will be examined by the examiners. The end examination shall consist of (a) Presentation and (b) Comprehensive viva-voce.
3	Students are expected to work on "Project Work" for about 6 hours per week (About 2 hour's self-study at residence and 12 hours in counselling session at study centre), during a semester. **Thus only those projects, demanding such study efforts on all those activities, listed in above, should be selected**.
4	**A single student will have to do a project.**

	Since. The student invests his energy, time and resources in a project. The project therefore should, have important focus on some relevant practical aspects. This will help student to justify his efforts on project.
5	Employed Students are allowed to complete "Project Work" in the industry where he/ she is employed or his/ her place of choice. Such a student has to identify a resource person in industry, who can take responsibility of guiding him in project work. Such person should be eligible to work as "ProjectGuide".
6	Study centre should assist unemployed students, in locating sponsored "Projects" from local industries. Students are encouraged to locate sponsored projects from the local industries. **But, in case, a student is unable to locate such project, he is also allowed to complete "Project Work" at his study center**.
7	**The Project Work must involve practical research work related to your selected discipline.**
8	Students have to finance expenditure on "Project" by his own. Hence students should select those projects, accordingly.
9	Each "Project Guide" may be assigned **maximum** 5 students.
10	The original design requirements **are not essential**, although highly encouraged. Hence, normally, projects should not be repeated. The same project undertaken in recent past, by past students, should be avoided. But it is most important that, students must put his independent study efforts on the project. Thus, student should gain practical project execution knowledge about making some useful product, after he goes through all projects completion steps listed above.
11	There project report should be file bound/spiral bound/hard bound and should have following format • **Title Page/Cover page** • **Certificate endorsed by Project Guide/Supervisor, Learner Support Center Coordinator and Head** • **Declaration for followed ethical practice and non-plagiarism** • **Acknowledgement** • **Abstract of the project** • **Table of Contents** • **List of Figures** • **List of Tables** • **Chapters of Project Report –** **Chapter 1: Introduction**: Background of the project, Need for the project, Brief idea of the project, Literature review, Aims and Objectives of the project **Chapter 2: Design and Methodology:** overview of the complete project, the scientific principles involved in the design of the project, Block Diagrams, Experimental/Theoretical Methodology/Circuit/Model/ materials required, etc. **Chapter 3: Testing, Conduct of Experiment/ Module**: Actual conduct of experiment, measurements, observations, etc. **Chapter 4: Analysis of Data:** Analysis of the data and observations received during experimentation **Chapter 5: Results, Discussion and Conclusions:** Discuss why the specifications were not met or the reasons for the failure, if any. Discussed the problems and difficulties encountered and how they were / can be eliminated. Discuss any extension work or modifications, which you want to suggest.

	Chapter 6: References: List the books, reference books, journals, websites, magazines and data manuals used, etc.
12	**Project Report Submission Process**: Student should prepare 2 copies of the Project Report. At the beginning, the respective Project Guide must approve both copies positively before the end examination of Project Work. Then respective Study Center Coordinator approves both copies of the Project Report. Student should submit one of these approved copies to the study center. The student should retain remaining one of these approved copies. Study center should preserve their copy of, all project reports, till the end examination of Project Work. **Even student must bring his own copy during this end examination**.
13	**Project Report Format:** 1. **The project report should be printed on only right side of A4 size (210 mm ´ 297 mm) paper. There is no minimum or maximum page number limit for the "Project Report", but report of minimum 50–70 pages is expected. University recommends only flexible binding for the "Project Report". But, if student wishes, he may also use spiral binding.** 2. **Margins should be as follows:·** ▪ **Left Margin : 40mm** ▪ **Right Margin : 20mm** ▪ **Top Margin : 20mm** ▪ **Bottom Margin : 27mm** 3. **Header should not be used. Footer, containing page number at the center should only be used, with footer margin of 25mm.** 4. **Text should be printed in font size of 12 points and at interline distance of 18 points. (That is 1.5 line spacing). Normally, figures should be embedded in the text, where there first reference occurs. But if necessary, figures may be grouped on separate pages. Figure should be numbered as 'Fig C.F', where 'C' is chapter number and 'F' is figure number. Figure number 'F' is reset back to 1 for each new chapter.** **Page Sequence: (1) Cover page as per specimen 1 (2) Certificate page as per specimen 2 (3) Acknowledgement page for the help offered by individuals and institution (4) Content page as per specimen 3. Following suggested scheme of chapters in project report then follows these first 4pages.**

	Specimen of Pages **Specimen 1** **Project Title- M.Sc. in .....** **Submitted by** **Name of Student-** **Name of Project Guide-** **Name of the Learner Support Center–** **Yashwantrao Chavan Maharashtra Open University** **20... - ...**	**Specimen 2** **Certificate** This is to certify that Mr/Ms..... .....(PRN ...) has successfully completed a project entitled ". ..... " in partial fulfilment for the requirement of **Master of Science in .....** Signature with Date Project Guide | LSC Coordinator Internal Examiner | External Examiner
14		

LEARNING RESOURCE DETAILS

Reference-Books: Explore additional details and reinforce learning, with this optional learning resource!			
MAT605 – RB1			
MAT605 – RB2			
Web Links: Explore additional details and reinforce learning, with this optional learning resource!			
RES505-WL1	Academic Integrity and Research Quality	Dec 2021	UGC
RES505-WL2	Guidance Document: Good Academic Research Practices	Sept 2020	UGC

COURSE OUTCOMES

After successful completion of this course, student should be able to

- Demonstrate proficiency in designing and implementing a research project in mathematics, including formulating research questions, hypotheses, and methodologies appropriate to the chosen topic.
- Develop advanced critical thinking skills to evaluate existing literature, mathematical models, and methodologies relevant to their research topic, identifying gaps, limitations, and opportunities for further investigation.
- Contribute to the advancement of mathematical knowledge by solving novel theoretical problems, proving new mathematical theorems, or developing innovative mathematical models and algorithms.
- Acquire skills in collecting, organizing, and analyzing data using mathematical techniques, statistical methods, or computational algorithms, and interpreting results

to draw meaningful conclusions.

- Communicate their research findings, methodologies, and theoretical developments effectively through scholarly writing, producing a well-structured thesis, research paper, or technical report adhering to academic standards and conventions.
- Present their research work orally to academic audiences, demonstrating the ability to articulate complex mathematical concepts, explain research methodology, and defend research outcomes during seminars, conferences, or thesis defenses.
- Uphold ethical principles and integrity in all aspects of the research process, including data collection, analysis, reporting, and dissemination, following institutional guidelines and professional standards for research ethics.

ELECTIVE COURSES

MAT606: DISCRETE MATHEMATICS

PROGRAMME INFORMATION

SN	Description	Details
1	University	Yashwantrao Chavan Maharashtra Open University Nashik - 422 222, Maharashtra, India Website: http://www.ycmou.ac.in/and http://ycmou.digitaluniversity.ac/
2	School	School of Sciences
3	Discipline	Science
4	Level	PG
5	Course Used in	V151: M.Sc.(Mathematics) {2023 Pattern} & V130 M.Sc.(Mathematics){2021 Pattern}

COURSE INFORMATION

Sem	Major	Code	Course Name	CR	CST	ST	CA	EE	TM	Type
03	DSE	MAT606	Discrete Mathematics	4	12	120	30	70	100	T

PRESUMED KNOWLEDGE AND LEARNING OBJECTIVES

Presumed Knowledge	Learning Objectives
For successful completion of this course, student should have successfully complete: • BSc/BA with Mathematics or equivalent from a recognized University/Board.	The objectives of this course are • To explain the concepts of permutation and combinations • To comprehend concepts of graph theory, Trees, Cut-sets • To elaborate properties of Boolean algebra, lattice and Boolean functions, Algebraic Systems defined by Lattices

UNITS

UN	Name of the Unit	CSs	Questions
01-01 01-02 01-03 01-04	**Permutations** **Combinations** **Generalized Permutations and Combinations** **Discrete Probability**	**CR 01**	As per evaluation pattern, on Each Credit, Student is required to answer • Very Short Answer Question (VSAQ), of 03 marks • Short Answer Question (SAQ), of 05 marks • Long Answer Question (LAQ) of 10 Marks (LAQ may contain sub-questions (a), (b) and so on.)
02-01 02-02 02-03 02-04	**Graphs** **Paths and Circuits** **Eulerian and Hamiltonian Paths and Circuits** **Planar Graphs**	**CR 02**	
03-01 03-02 03-03 03-04	**Trees** **Rooted and Binary Trees** **Spanning Trees** **Cut-Sets**	**CR 03**	

04-01 04-02 04-03 04-04	**Lattices and Algebraic Systems** **Basic Properties of Algebraic Systems Defined by Lattices** **Boolean Lattices and Boolean Algebras** **Boolean Functions and Boolean Expressions**	**CR 04**	

DETAILED SYLLABUS

UN	Detailed Syllabus of the Unit	CR
1-1	**Permutations:** Introduction, Definitions, Circular Permutations, Permutations with repetitions	**CR 01**
1-2	**Combinations:** Introduction, Definitions	
1-3	**Generalized Permutations and Combinations:** Introduction, Definitions, Permutations and Combinations with unlimited repetitions	
1-4	**Discrete Probability:** Sample space, Discrete Sample space, Simple and Compound event	
2-1	**Graphs:** Introduction to graph theory, types of graphs, Basic terminology, Subgraphs, Graph isomorphism, Connectedness in simple graphs, Matrix representation of graphs	**CR 02**
2-2	**Paths and Circuits:** Distance in graphs: Eccentricity, Radius, Diameter, Center, Weighted graphs Dijkstra's algorithm to find the shortest distance paths in graphs and digraphs	
2-3	**Eulerian and Hamiltonian Paths and Circuits:** Necessary and sufficient conditions for Euler circuits and paths in simple, undirected graphs. Some applications of graphs, Traveling Salesman's Problem, Nearest neighbor method.	
2-4	**Planar Graphs:** Euler's formula. Kuratowski's theorem, Non planar graphs, Detection of Planarity, Geometric Dual, Coloring of graphs, Chromatic number, Chromatic polynomial.	
3-1	**Trees:** Elementary properties of trees, Center, Pendant Vertices in a Tree, Distance and Centers in a Tree,Minimally connected graph.	**CR 03**
3-2	**Rooted and Binary Trees:** Rooted trees, Binary trees, Trees as models. Properties of trees.	
3-3	**Spanning Trees:** Minimum spanning trees. Fundamental Circuits, finding all Spanning Trees of a Graph, Spanning Trees in a Weighted Graph, Prim's and Kruskul's Algorithms.	
3-4	**Cut-Sets:** Cut-vertex, Cut-Edge, Some Properties of a Cut-Set, Fundamental circuits and cut-sets, Connectivity and Separability.	
4-1	**Lattices and Algebraic Systems:** Introduction, Principle of Duality, Properties of Lattices, Lattice as an Algebraic system, Sub Lattice, Bounded Lattice, Complements, Complete Lattice.	**CR 04**
4-2	**Basic Properties of Algebraic Systems Defined by Lattices:** Distributive Lattice, Complemented Lattice, Isomorphic Lattice, Modular Lattice.	
4-3	**Boolean Lattices and Boolean Algebras:** Properties of Boolean Algebra, Boolean sub-algebra, Homomorphism of Boolean Algebra, Order relation in Boolean Algebra.	
4-4	**Boolean Functions and Boolean Expressions:** Fundamental forms of Boolean functions, Normal forms of Boolean functions, Disjunctive and Conjunctive normal form Examples.	

LEARNING RESOURCE DETAILS

LR Code	Title Author	Edition Year	ISBN Publisher
Course Website Link for (1) Mobile and Online Lectures, (2) Discussion Forum for online interaction and (3) Self-Test for each CR Block, Continuous Assessment Test and End Examination			
CW-MAT606			
Text-Books			
MAT606-T01	Discrete Mathematics Dr. M. T. Gophane & Prof. Kishor F. Pawar	2022	978-93-95855-12-9 YCMOU
Reference-Books: Explore additional details and reinforce learning, with this optional learning resource!			
MAT606 –RB1	Elements of Discrete Mathematics, Liu, C L. (Chung Laung)	2nd Edition1985	0-07-038133-X
MAT606 –RB2	Discrete mathematics with graph theory, Edgar G. Goodaire, Michael M. Parmenter	2nd Edition2002	0-13-092000-2
MAT606 –RB3	Discrete Mathematics and its Applications Kenneth H. Rosen	7thEdition2012	978-0-07-338309-5
MAT606 –RB4	Graph Theory, F. Harary	1969	Addition Wesley
MAT606 –RB5	A First look at Graph Theory, John Clark and Derek Allan Holton	1991	Prentice Hall 81-7023-463-8
MAT606 –RB6	Graph Theory With Applications to Engineering and Computer Science, N. Deo	1974	Prentice Hall of India 0-13-363473-6
MAT606 –RB7	Boolean Algebra and Graph Theory J N Salunke	2000	Laxmi Prakashan
MAT606 –RB8	Combinatorics, Dr. M. T. Gophane	2014	978-81-8486-691-9
CD / DVD: Explore additional details and reinforce learning, with this optional learning resource!			
MAT606 -CD1			
Web Links: Explore additional details and reinforce learning, with this optional learning resource!			
MAT606-WL1			

COURSE OUTCOMES

After successful completion of this course, student should be able to

- Solve problems on permutation and combinations, discrete Probability
- Understand concepts of graph theory, Trees, Cut-sets
- Understand properties of Boolean algebra, lattice and Boolean functions, Algebraic Systems defined by Lattices

MAT607: DIFFERENTIAL GEOMETRY

PROGRAMME INFORMATION

SN	Description	Details
1	University	Yashwantrao Chavan Maharashtra Open University Nashik - 422 222, Maharashtra, India Website: http://www.ycmou.ac.in/and http://ycmou.digitaluniversity.ac/
2	School	School of Sciences
3	Discipline	Science
4	Level	PG
5	Course Used in	V151: M.Sc.(Mathematics) {2023 Pattern} & V130 M.Sc.(Mathematics){2021 Pattern}

COURSE INFORMATION

Sem	Major	Code	Course Name	CR	CST	ST	CA	EE	TM	Type
03	DSE	MAT607	Differential Geometry	4	12	120	30	70	100	T

PRESUMED KNOWLEDGE AND LEARNING OBJECTIVES

Presumed Knowledge	Learning Objectives
For successful completion of this course, student should have successfully complete: • BSc/BA with Mathematics or equivalent from a recognized University/Board.	The objectives of this course are • To describe curves and surfaces and label their equations • To introduce about representation of the curves and surfaces in different forms and identify their nature • To illustrate construction of various surfaces • To study computation of various parameters related to curves and surfaces and justify their behavior

UNITS

UN	Name of the Unit	CSs	Questions
01-01 01-02 01-03 01-04	**Euclidean Space** **Curves** **Frenet Apparatus and Frenet Formulae** **Isometries of R^3**	**CR 01**	As per evaluation pattern, on Each Credit, Student is required to answer • Very Short Answer Question (VSAQ), of 03 marks • Short Answer Question (SAQ), of 05 marks • Long Answer Question (LAQ) of 10 Marks (LAQ may contain sub-questions (a), (b) and so on.)
02-01 02-02 02-03 02-04	**Covariant Derivative** **Surfaces in R^3** **Patch computation of a Surface** **Shape Operator**	**CR 02**	
03-01 03-02 03-03 03-04	**Gaussian and Mean Curvatures** **Gauss Map** **Fundamental Forms** **Geodesic Curvature**	**CR 03**	
04-01 04-02 04-03 04-04	**Some Special Curves on a Surface** **Geodesic Differential Equations** **Isometry of Surfaces** **Surfaces of Constant Curvature**	**CR 04**	

DETAILED SYLLABUS

UN	Detailed Syllabus of the Unit	CR
1-1	**Euclidean Space**: Euclidean space of 3- dim., Tangent vectors and vector fields on R^3, Natural coordinate functions, Natural frame fields, Euclidean coordinate functions, Directional derivative.	CR 01
1-2	**Curves:** Plane curves, velocity vector to a curve, reparameterization of a curve, Regular curve, arc length of a curve, unit speed reparameterization, Frame, Norm of a vector, Euclidean distance, Vector field on a curve, Parallel vector field on a curve.	
1-3	**Frenet Apparatus and Frenet Formulae:** Frenet frame field, The Frenet formulae for the unit speed curve, Spherical curve, Frenet formulae for arbitrary speed curve, Cylindrical Helix.	
1-4	**Isometries of R^3**: Isometry, Translation, Rotation, Orthogonal transformation.	
2-1	**Covariant derivative**: Covariant derivative of a vector field, Properties of covariant derivative, Lie bracket.	CR 02
2-2	**Surfaces in R^3:** Regular mapping, Coordinate patch and proper patch, Surface, Monge patch, Criteria for a surface, surface of revolution.	
2-3	**Patch Computation of a Surface**: Patch computation, Parametrisation of a region X(D) in M, Parametrisation of a surface of revolution, Torus of revolution, Tangents and normal, Normal vector field on a surface.	
2-4	**Shape Operator:** Shape operator, Normal Curvature, Normal section of a surface, Principal curvature, Principal direction, Umbilic points, Euler's Theorem.	
3-1	**Gaussian and Mean Curvatures:** Gaussian curvature and Mean curvature, Flat space, Minimal space, Computational techniques, Sign of Gaussian curvature.	CR 03
3-2	**Gauss Map:** Gauss map, Quadric surface, Geometrical interpretation of Principal curvature.	
3-3	**Fundamental Forms:** Arc length of a curve on a surface, The first and the second fundamental forms of a surface, Computation of a normal curvature of a curve on a surface patch.	
3-4	**Geodesic Curvature:** Geodesic curvature of a curve on a surface, Relation between the curvature, normal curvature and the geodesic curvature of a curve on a surface, Expression for geodesic curvature of a curve on a surface, shape operator for the Cartesian equation of the surface, Gaussian and mean curvatures of Cartesian equation of a surface.	
4-1	**Some Special Curves on a Surface**: Lines of Curvature, Differential equation of lines of curvature, Asymptotic directions and asymptotic curves, Characterization of an asymptotic curve, Geodesics.	CR 04
4-2	**Geodesic Differential Equations:** Differential equations of a geodesic, Geodesic as a shortest path, Conditions for parametric curves to be geodesics, Geodesic parallels.	
4-3	**Isometries of Surfaces**: Isometry of surfaces, Conformal mapping, Gauss's Remarkable Theorem.	
4-4	**Surfaces of Constant Curvature:** Surfaces of constant Gaussian curvature, Weingarten Equations, Surfaces of constant mean curvature, Gauss Equations, Codazzi-Mainardi equations.	

LEARNING RESOURCE DETAILS

LR Code	Title Author	Edition Year	ISBN Publisher
Course Website Link for (1) Mobile and Online Lectures, (2) Discussion Forum for online interaction and (3) Self-Test for each CR Block, Continuous Assessment Test and End Examination			
CW-MAT607			
Text-Books			
MAT607-T01	Differential Geometry, Dr. L. N. Katkar	2021	978-93-91514-63-1 YCMOU
Reference-Books: Explore additional details and reinforce learning, with this optional learning resource!			
MAT607 – RB1	An introduction to Differential Geometry, T J Wilmore		Oxford University Press
MAT607 – RB2	Elementary Differential Geometry, Andrew Pressley	2009	Springer-Verlag, London. 978-81-8128-143-2
MAT607 – RB3	Elementary Differential Geometry, Barrat O'Neill	2006	Academic Press, 978-0-12-088735-4
MAT607 – RB4	Differential Geometry- First Course, D. Somasundaram	2010	Narosa Publishing House, New Dehli.
MAT607 – RB5	Differential Geometry C Weatherburn		
MAT607 – RB6	Differential Geometry, K. S. Amur and et al	2010	Narosa Publishing House, New Dehli.
MAT607 – RB7	Elements of Differential Geometry, Millman, R. and Parker, G. D	1977	Prentice-Hallof India Pvt. Ltd.
CD / DVD: Explore additional details and reinforce learning, with this optional learning resource!			
MAT609 - CD1			
Web Links: Explore additional details and reinforce learning, with this optional learning resource!			
MAT607-WL1	NPTEL, SWAYAM		

COURSE OUTCOMES

After successful completion of this course, student should be able to

- Describe curves and surfaces and label their equations
- Represent the curves and surfaces in different forms and identify their nature
- Construct various surfaces
- Compute various parameters related to curves and surfaces and justify their behavior

MAT608: INTEGRAL TRANSFORMS

PROGRAMME INFORMATION

SN	Description	Details
1	University	Yashwantrao Chavan Maharashtra Open University Nashik - 422 222, Maharashtra, India Website: http://www.ycmou.ac.in/and http://ycmou.digitaluniversity.ac/
2	School	School of Sciences
3	Discipline	Science
4	Level	PG
5	Course Used in	V151: M.Sc.(Mathematics) {2023 Pattern} & V130 M.Sc.(Mathematics){2021 Pattern}

COURSE INFORMATION

Sem	Major	Code	Course Name	CR	CST	ST	CA	EE	TM	Type
03	DSE	MAT608	Integral Transforms	4	12	120	30	70	100	T

PRESUMED KNOWLEDGE AND LEARNING OBJECTIVES

Presumed Knowledge	Learning Objectives
For successful completion of this course, student should have successfully complete: • BSc/BA with Mathematics or equivalent from a recognized University/Board.	The objectives of this course are • Develop adequate knowledge of fundamentals of Fourier Integrals, Fourier Transforms, Inverse Fourier Transforms • To study Laplace Transform, its properties, Inverse LT & its applications • To study Mellin Transform & applications • To introduce Z- Transforms & InverseZ-transform

UNITS

UN	Name of the Unit	CSs	Questions
01-01 01-02 01-03 01-04	**Fourier Integral** **Fourier Transforms** **Inverse Fourier Transforms** **Applications of Fourier Transforms**	**CR 01**	As per evaluation pattern, on Each Credit, Student is required to answer • Very Short Answer Question (VSAQ), of 03 marks • Short Answer Question (SAQ), of 05 marks • Long Answer Question (LAQ) of 10 Marks (LAQ may contain sub-questions (a), (b) and so on.)
02-01 02-02 02-03 02-04	**Laplace Transform** **Properties of Laplace Transform** **The inverse Laplace Transform** **Applications of Laplace Transform**	**CR 02**	
03-01 03-02 03-03 03-04	**The Mellin Transform** **Inverse Mellin Transform** **Applications of Mellin transform** **The Henkel Transform**	**CR 03**	

04-01 04-02 04-03 04-04	**Applications of Hankel transform** **Finite transforms** **Z- Transforms** **Inverse *Z*-transform**	**CR 04**	

DETAILED SYLLABUS

UN	Detailed Syllabus of the Unit	CR
1-1	**Fourier Integrals:** Preliminaries of Special Functions such as the Gamma, Error and Bessel functions, Fourier Integral Representations, Proof of the Fourier Integral Theorem.	CR 01
1-2	**Fourier Transforms**: Fourier Transform Pairs, Properties of the Fourier Transform, Fourier Cosine and Sine Transforms, Transforms of More Complicated Functions.	
1-3	**Inverse Fourier Transforms**: Inverse Fourier Transform, Inverse Fourier Sine Transform, Inverse Fourier Cosine Transform, Modulation Theorem, Convolution Theorem.	
1-4	**Applications of Fourier Transforms**: Boundary Value Problems, Heat Conduction in Solids, Mechanical Vibrations, Potential Theory.	
2-1	**Laplace Transform**: Introduction, The Transforms of Some Typical Functions.	CR 02
2-2	**Properties of Laplace Transform**: Basic properties, Transforms of More Complicated Functions.	
2-3	**The inverse Laplace Transform**: Properties of Inverse Laplace Transform, Partial fractions, Series method, Convolution theorem, Complex Inversion Formula.	
2-4	**Applications of Laplace Transform:** Evaluating Integrals, Solutions of ODEs, Solutions of PDEs, Solutions of Linear Integral Equations.	
3-1	**The Mellin Transform**: Evaluation of Mellin Transforms, Operational properties.	CR 03
3-2	**Inverse Mellin Transform:** Complex Variable Method, Inverse Transforms, Convolution theorem, Transforms in Polar coordinates.	
3-3	**Applications of Mellin transform:** Summation of series, Products of random variables, Distribution of potential in a wedge.	
3-4	**The Henkel Transform**: Introduction, Evaluation of Henkel Transforms, Operational properties.	
4-1	**Applications of Hankel transform:** Convolution theorem, Potential problems, Variation problems.	CR 04
4-2	**Finite Transforms**: Finite Fourier Transform: Finite Sine and cosine Fourier Transforms, Applications.	
4-3	**Z- Transform**: Evaluation of Z-Transforms, Operational properties.	
4-4	**Inverse Z-transform:** Inverse Z-transforms and their properties, Convolution theorem, Solutions of Difference Equations.	

LEARNING RESOURCE DETAILS

LR Code	Title Author	Edition Year	ISBN Publisher
Course Website Link for (1) Mobile and Online Lectures, (2) Discussion Forum for online interaction and (3) Self-Test for each CR Block, Continuous Assessment Test and End Examination			
CW-			

MAT608			
Text-Books			
MAT608-T01	Integral Transforms, Dr. S. D. Katore & Dr. D. D. Pawar	2020	978-93-91514-62-4 YCMOU
Reference-Books: Explore additional details and reinforce learning, with this optional learning resource!			
MAT608 – RB1	Integral Transforms for Engineers, L. C. Andrews, B. K. Shivamoggi	2004	Prentice Hall of India Pvt. Ltd., New Delhi
MAT608 – RB2	Fourier Transforms, Sneddon I N	1951	McGraw Hill
MAT608 – RB3	Fourier Transforms and Its Applications, Bracemell	3rd, 1999	McGraw-Hill
MAT608 – RB4	Fourier Analysis an Introduction, Elias M Stein &Rami Shakarchi,		Oxford University Press
MAT608 – RB5	Fourier and Laplace Transforms R.J. Beereds, H.G. Morsche , J C Vanden Berg & E.M. Vandevire ,	2003	Cambridge University Press.
MAT608 – RB6	Fourier and Wavelet Analysis George Bachman Lawrence Narici		Springer
MAT608 – RB7	Fourier Transform in complex domain E.A. Paley and Norbert Wiener		American Mathematical Society
MAT608 – RB8	Mathematical Method T. M. Karade, N. T. Karade	Third Edition, 2017	Sonu Nilu
CD / DVD: Explore additional details and reinforce learning, with this optional learning resource!			
MAT608 - CD1			
Web Links: Explore additional details and reinforce learning, with this optional learning resource!			
MAT608-WL1			

COURSE OUTCOMES

After successful completion of this course, student should be able to

- Solve problems on differential and integral equations using Laplace, Fourier transform techniques
- Solve difference Equations by using Z transforms
- Solve problems based on Mellin Transform and Hankel transform techniques

SEMESTER 04

MAT609: CLASSICAL MECHANICS

PROGRAMME INFORMATION

SN	Description	Details
1	University	Yashwantrao Chavan Maharashtra Open University Nashik - 422 222, Maharashtra, India Website: http://www.ycmou.ac.in/and http://ycmou.digitaluniversity.ac/
2	School	School of Sciences
3	Discipline	Science
4	Level	PG
5	Course Used in	V151: M.Sc.(Mathematics) {2023 Pattern} & V130 M.Sc.(Mathematics){2021 Pattern}

COURSE INFORMATION

Sem	Major	Code	Course Name	CR	CST	ST	CA	EE	TM	Type
04	DSC	MAT609	Classical Mechanics	4	12	120	30	70	100	T

PRESUMED KNOWLEDGE AND LEARNING OBJECTIVES

Presumed Knowledge	Learning Objectives
For successful completion of this course, student should have successfully complete: • BSc/BA with Mathematics or equivalent from a recognized University/Board.	The objectives of this course are • To Explain Euler's variational principles • To illustrate application of D'Alembert's Principle, Lagrange's equation, Hamiltonians Principle, Hamilton's equation and Hamilton Jacobi equation to form differential equation as well as its solution of various real existing systems. • To study formulation of Poisson's brackets, Lagrange's bracket, canonical transformation for solution of equations.

UNITS

UN	Name of the Unit	CSs	Questions
01-01 01-02 01-03 01-04	**Mechanics of System of Particles** **D'Alembert's Principle and Lagrange's Equations** **Central Force Motion** **Kepler's Laws and Virial Theorem**	**CR 01**	As per evaluation pattern, on Each Credit, Student is required to answer • Very Short Answer Question (VSAQ), of 03 marks • Short Answer Question (SAQ), of 05 marks
02-01 02-02 02-03 02-04	**Calculus of Variation** **Euler's Equation and its Applications** **Hamilton's Principle** **Hamilton's Equation of Motion**	**CR 02**	

03-01 03-02 03-03 03-04	**Routh Procedure and the Least Action Principle** **Canonical Transformations** **Invariance under Canonical Transformations** **Lagrange and Poisson Brackets**	**CR 03**	• Long Answer Question (LAQ) of 10 Marks (LAQ may contain sub-questions (a), (b) and so on.)
04-01 04-02 04-03 04-04	**Rigid Body Motion- Rotations in Plane and Space** **Eulerian Angles** **A Moving Coordinate Frame** **Rotational Dynamics of a Rigid Body**	**CR 04**	

DETAILED SYLLABUS

UN	Detailed Syllabus of the Unit	CR
1-1	**Mechanics of a System of Particles:** Mechanics of a particle, Mechanics of a system of particles, Degrees of freedom and generalized coordinates.	**CR 01**
1-2	**D'Alembert's Principle and Lagrange's Equations:** D'Alembert's principle, Derivation of Lagrange's equations for conservative system, Generalized potential, Rayleigh's dissipation function	
1-3	**Central Force Motion:** Equivalent one body problem, Central force field, Motion in one dimension, Classification of central orbits, Differential equation for the orbit, Integrable power law force field	
1-4	**Kepler's Laws and Virial Theorem:** Kepler's first law, Kepler's second law, Kepler's third law, Virial theorem	
2-1	**Calculus of Variation:** Preliminaries, Functional, Continuity of a functional	**CR 02**
2-2	**Euler's Equation and its Applications:** Variation of y(x) and I[y(x)], An elementary problem in the CV, Invariance of Euler equation, Applications of Euler equation.	
2-3	**Hamilton's Principle:** Hamilton's principle for conservative system, Extension of Hamilton's principle to nonconservative holonomic system, Lagrange's equation for nonholonomic conservative systems.	
2-4	**Hamilton's Equation of Motion:** Derivation of the Hamilton's canonical equations, Hamilton's equations from variational principle.	
3-1	**Routh Procedure and the Least Action Principle:** Routhian of a mechanical system, The least action principle.	**CR 03**
3-2	**Canonical Transformations:** Some transformations, Canonical or contact transformations, Generating function of a canonical transformation.	
3-3	**Invariance under Canonical Transformations:** Bilinear covariant of the Pfaffian differential form, Theorem of Poincare, Infinitesimal canonical transformation	
3-4	**Lagrange and Poisson Brackets:** Lagrange bracket, Poisson bracket, Equations of motion in Poisson bracket, Canonical invariance of the Poisson bracket, Jacobi identity, Angular momentum and Poisson brackets, Relation between Lagrange and Poisson brackets	
4-1	**Rigid Body Motion- Rotations in Plane and Space:** Preliminaries, Rotations in the plane, Rotations in 3-space.	**CR 04**
4-2	**The Euler Angles:** Transformation matrix in terms of Euler angles, The Euler's	

	theorem, Finite rotations, Infinitesimal rotations.	
4-3	**A Moving Coordinate Frame:** Translational accelerated frame, A rotating coordinate frame, Acceleration in a rotating system, Application to the rotating earth	
4-4	**Rotational Dynamics of a Rigid Body:** Mathematical back ground, Angular momentum and inertia tensor, Principal axes, The Euler equations of motion.	

LEARNING RESOURCE DETAILS

LR Code	Title Author	Edition Year	ISBN Publisher
Course Website Link for (1) Mobile and Online Lectures, (2) Discussion Forum for online interaction and (3) Self-Test for each CR Block, Continuous Assessment Test and End Examination			
CW-MAT609			
Text-Books			
MAT609-T01	Classical Mechanics, Dr. T.M. Karade	2019	978-93-91514-36-5 YCMOU
Reference-Books: Explore additional details and reinforce learning, with this optional learning resource!			
MAT609 – RB1	Classical Mechanics, H. Goldstein	1980	Narosa
MAT609 – RB2	Classical Mechanics, Gupta, Kumar, Sharma	2006	Pragati
MAT609 – RB3	Calculus of variations with application to Physics & Engineering, Robert Weinstock	1952	McGrow-Hill book comp.
MAT609 – RB4	A treatise on Classical Mechanics, T M Karade and Nilay T Karade	2019	SonuNilu Publication, Nagpur
MAT609 – RB5	Problem Book in Classical Mechanics, L N Katkar	2014	Narosa Publication, New Delhi
CD / DVD: Explore additional details and reinforce learning, with this optional learning resource!			
MAT609 - CD1			
Web Links: Explore additional details and reinforce learning, with this optional learning resource!			
MAT609-WL1			

COURSE OUTCOMES

After successful completion of this course, student should be able to

- Use Euler's variational principles to solve real life problems.
- Apply D'Alembert's Principle, Lagrange's equation, Hamiltonians Principle, Hamilton's equation and Hamilton Jacobi equation to form differential equation as well as its solution of various real existing systems.
- Formulate Poisson's brackets, Lagrange's bracket, and canonical transformation for solution of equations.

MAT610: FUNCTIONAL ANALYSIS

PROGRAMME INFORMATION

SN	Description	Details
1	University	Yashwantrao Chavan Maharashtra Open University Nashik - 422 222, Maharashtra, India Website: http://www.ycmou.ac.in/and http://ycmou.digitaluniversity.ac/
2	School	School of Sciences
3	Discipline	Science
4	Level	PG
5	Course Used in	V151: M.Sc.(Mathematics) {2023 Pattern} & V130 M.Sc.(Mathematics){2021 Pattern}

COURSE INFORMATION

Sem	Major	Code	Course Name	CR	CST	ST	CA	EE	TM	Type
04	DSC	MAT610	Functional Analysis	4	12	120	30	70	100	T

PRESUMED KNOWLEDGE AND LEARNING OBJECTIVES

Presumed Knowledge	Learning Objectives
For successful completion of this course, student should have successfully complete: • BSc/BA with Mathematics or equivalent from a recognized University/Board.	The objectives of this course are • To introduce the concepts of normed spaces, Banach space and Hilbert spaces • To explain how the notion of norm induces metric on a linear space and then think of sequences, continuity and completeness over linear spaces • To illustrate the application of uniform boundedness principal, Hahn-Banach theorem for solution of differential equations.

UNITS

UN	Name of the Unit	CSs	Questions
01-01 01-02 01-03 01-04	**Banach Spaces** **Continuous Linear Transformation** **Hahn Banach Theorem** **Natural Embedding**	**CR 01**	As per evaluation pattern, on Each Credit, Student is required to answer • Very Short Answer Question (VSAQ), of 03 marks • Short Answer Question (SAQ), of 05 marks • Long Answer Question (LAQ) of 10 Marks (LAQ may contain sub-questions (a), (b) and so on.)
02-01 02-02 02-03 02-04	**Open Mapping Theorem** **Conjugate of an Operator** **Hilbert Spaces** **Orthogonal Complements**	**CR 02**	
03-01 03-02 03-03 03-04	**Conjugate Spaces** **Adjoint of an Operator** **Different Types of Operators** **Projections**	**CR 03**	
04-01 04-02 04-03 04-04	**Spectral Resolution** **Matrices** **Spectrum of an Operator** **The Spectral Theorem**	**CR 04**	

DETAILED SYLLABUS

UN	Detailed Syllabus of the Unit	CR
1-1	**Banach Spaces**: Normed linear space, Banach space, The definition and examples, construction of new normed spaces.	CR 01
1-2	**Continuous Linear Transformation**: Bonded, Continuous linear transformation some definitions and theorems.	
1-3	**Hahn Banach Theorem**: Conjugate Space, Functional, Lemma, The Hahn Banach Theorem and its consequences.	
1-4	**Natural Embedding:** Second conjugate space, Natural imbedding of N in N**, Reflexive space, Compact Hausdorff of the closed unit sphere.	
2-1	**Open Mapping Theorem:** Definitions of Open Sphere, Open Map,Lemma, Open mapping theorem, Closed graph theorem and their consequences.	CR 02
2-2	**Conjugate of an Operator:** Conjugate of an operator, Uniform boundedness theorem, and its consequences.	
2-3	**Hilbert Spaces:** The definition and examples of Hilbert space, Schwarz inequality, Parallelogram law for Hilbert spaces and its applications.	
2-4	**Orthogonal Complements:** Orthogonal complement, Pythagorean theorem, Orthonormal sets, Bessels inequality and its consequences, Gram-Schmidt Orthogonalization.	
3-1	**The Conjugate Spaces:** The conjugate space H*, Natural correspondence between H and H*; H and H**.	CR 03
3-2	**Adjoint of an Operator:** Difference between the conjugate and adjoint of T, Arithmetic and norm properties of adjoint operation.	
3-3	**Different Types of Operators:** Self adjoint operators, Normal and Unitary operators, Existence of non-normal operators, Geometric significance of the operators.	
3-4	**Projections:** Projections, Perpendicular projection, Reduceness of closed linear subspace, Sum of projections.	
4-1	**Spectral Resolution:** Eigen value and eigen vector of an operator, Spectral resolution of T.	CR 04
4-2	**Matrices:** Definitions of nonsingular matrix, Similar matrices, Matrix algebra etc, non-singularity of the operator T.	
4-3	**Spectrum of an Operator:** Properties of determinant, Spectrum of an operator, eigenvalues of the operator T.	
4-4	**The Spectral Theorem:** Definition of spectral resolution of T, Mi reduces T, The Spectral theorem, Uniqueness theorem.	

LEARNING RESOURCE DETAILS

LR Code	Title Author	Edition Year	ISBN Publisher
Course Website Link for (1) Mobile and Online Lectures, (2) Discussion Forum for online interaction and (3) Self-Test for each CR Block, Continuous Assessment Test and End Examination			
CW-MAT610			
Text-Books			
MAT610-	Functional Analysis,	2023	978-93-95855-78-5

T01	Dr. B. Surendra Reddy & Dr. Rupali S. Jain		YCMOU
Reference-Books: Explore additional details and reinforce learning, with this optional learning resource!			
MAT610 – RB1	Introduction to Topology and Modern Analysis , G. F. Simmons	1963	Tata McGraw Hill
MAT610 – RB2	Functional Analysis, B.V. Limaye		Wiley Eastern Ltd.
MAT610 – RB3	Foundations of Functional Analysis, S. Ponnusamy		Narosa Publishing House
MAT610 – RB4	Functional Analysis, G. Bachman and L. Narici		
MAT610 – RB5	Introductory Functional Analysis with Applications, Kreyszig	1966	John Wiley & Sons
CD / DVD: Explore additional details and reinforce learning, with this optional learning resource!			
MAT610 - CD1			
Web Links: Explore additional details and reinforce learning, with this optional learning resource!			
MAT610-WL1			

COURSE OUTCOMES

After successful completion of this course, student should be able to

- Know the concepts of normed spaces, Banach space and Hilbert spaces
- Explain how the notion of norm induces metric on a linear space and then think of sequences, continuity and completeness over linear spaces
- Apply uniform boundedness principal, Hahn-Banach theorem for solution of differential equations

MAT611: PROGRAMMING IN PYTHON

PROGRAMME INFORMATION

SN	Description	Details
1	University	Yashwantrao Chavan Maharashtra Open University Nashik - 422 222, Maharashtra, India Website: http://www.ycmou.ac.in/and http://ycmou.digitaluniversity.ac/
2	School	School of Sciences
3	Discipline	Science
4	Level	PG
5	Course Used in	V151: M.Sc.(Mathematics) {2023 Pattern}

COURSE INFORMATION

Sem	Major	Code	Course Name	CR	CST	ST	CA	EE	TM	Type
04	DSC	MAT611	Programming in Python	4	12	120	50	50	100	P

PRESUMED KNOWLEDGE AND LEARNING OBJECTIVES

Presumed Knowledge	Learning Objectives
For successful completion of this course, student should have successfully complete: • BSc/BA with Mathematics or equivalent from a recognized University/Board.	The objectives of this course are • To understand why Python is a useful scripting language for developers. • To learn how to use lists, tuples, and dictionaries in Python programs. • To learn and understand python looping, control statements and string manipulations. • To acquire programming skills in core Python. • To learn and understand Python programming basics and paradigm. • To learn the concepts of visualization of data and database connectivity. • To develop the ability to write database applications in Python

Note: (1) The theoretical background relevant to the experiments listed below should be discussed during practical sessions only.
(2) Wherever possible, the output should be presented in graphical form also.

LAB ACTIVITY

SN	Title of Activity	CR
	Write simple programs in python language/code for SN 1 to 17	
1	Introduction to Python, Python Data Types-I	CR 01
2	Python Data Types- II	
3	Control statements in Python-I	
4	Control statements in Python-II	
5	Application: Matrices	CR 02
6	Application: Determinants, system of Linear Equations	
7	Application: System of equations	
8	Application: Eigenvalues, Eigenvectors	

9	Application: Roots of equations	
10	Application: Numerical integration	CR 03
11	List comprehensions	
12	Graph Plotting	
13	Data Visualization	
14	Dictionary and Sorting, Minimum and Maximum	CR 04
15	Application to Computational Geometry-I	
16	Study of Graphical aspects of Two dimensional transformation matrix using Matplotlib	
17	Study of Operational Research in Python	

LEARNING RESOURCE DETAILS

LR Code	Title Author	Edition Year	ISBN Publisher
Text-Books			
Reference-Books: Explore additional details and reinforce learning, with this optional learning resource!			
MAT 611 - RB1	Fundamentals of Python: From First Programs to Data Structure, Kenneth A. Lambert	2010	Martin Osborne, 2010, Course Technology, Cengage Learning.
MAT 611 – RB2	Python: Notes for Professionals, Goalkicker.com, Free Programming books	2010	
MAT 611 – RB3	Introduction to Computing and Programming in Python, Guzdial, M. J.		Pearson India
MAT 611 – RB4	Introduction to Computing Using Python, Perkovic, L	2015	John Wiley
MAT 611 – RB5	Zelle, J., Python Programming: An Introduction to Computer Science, Franklin, Beedle and Associates Inc		
MAT 611 – RB6	Basics of Linear Algebra for Machine Learning, Jason Brownlee		
CD / DVD: Explore additional details and reinforce learning, with this optional learning resource!			
-CD1			
Web Links: Explore additional details and reinforce learning, with this optional learning resource!			
MAT 611 – WL1	Spoken Tutorial by IITB Link: Getting started with IPython - English | spoken-tutorial.org		

COURSE OUTCOMES

After successful completion of this course, student should be able to

- Explain basic principles of Python programming language
- Implement object oriented concepts
- Demonstrate the use of Python in Mathematics such as operations research and computational Geometry etc.
- Study graphics and design and implement a program to solve a real world problem
- Implement the concepts of data with python and database connectivity

MAT612: RESEARCH PROJECT

PROGRAMME INFORMATION

SN	Description	Details
1	University	Yashwantrao Chavan Maharashtra Open University Nashik - 422 222, Maharashtra, India Website: http://www.ycmou.ac.in/and http://ycmou.digitaluniversity.ac/
2	School	School of Sciences
3	Discipline	Science
4	Level	PG
5	Course Used in	V151: M.Sc.(Mathematics) {2023 Pattern}

COURSE INFORMATION

Sem	Other Course	Code	Course Name	CR	CST	ST	CA	EE	TM	Type
04	RP	MAT612	Research Project	6	12	120	75	75	150	PW

PRESUMED KNOWLEDGE AND LEARNING OBJECTIVES

Presumed Knowledge	Learning Objectives
For successful completion of this course, student should have successfully complete: • BSc/BA with Mathematics or equivalent from a recognized University/Board.	The objectives of this course are • To gain expertise in Research Design and Methodology • To acquire skills in collecting and analyzing data • To learn effective time management and project planning skills • To develop problem-solving skills and the ability to adapt research strategies

GUIDELINES:

No	Guidelines for the Students and Study Centers for the conduct of Project
1	The "Project Work" course aims to imbibe in students the principle that working is learning. Learning and working are two sides of the same coin and thus, work experience enhances the learning.
2	This course is based on preliminary research oriented topics both in theory and experiment. The subject expert/ counsellor will act as supervisors for the projects. Project shall be on the current and relevant topics and issues. Project topic is jointly finalized by the student and the project supervisors through discussion. At the completion of the project by the semester end, the student will submit a Project Report in the form of Dissertation which will be examined by the examiners. The end examination shall consist of (a) Presentation and (b) Comprehensive viva-voce.
3	Students are expected to work on "Project Work" for about 6 hours per week (About 2 hour's self-study at residence and 12 hours in counselling session at Lerner Support Center), during a semester. **Thus only those projects, demanding such study efforts on all those activities, listed in above, should be selected**.
4	**A single student will have to do a project.**

	Since. The student invests his energy, time and resources in a project. The project therefore should, have important focus on some relevant practical aspects. This will help student to justify his efforts on project.
5	Employed Students are allowed to complete "Project Work" in the industry where he/ she is employed or his/ her place of choice. Such a student has to identify a resource person in industry, who can take responsibility of guiding him in project work. Such person should be eligible to work as "Project Guide".
6	Lerner Support Center should assist unemployed students, in locating sponsored "Projects" from local industries. Students are encouraged to locate sponsored projects from the local industries. **But, in case, a student is unable to locate such project, he is also allowed to complete "Project Work" at his study center**.
7	**The Project Work must involve practical research work related to your selected discipline.**
8	Students have to finance expenditure on "Project" by his own. Hence students should select those projects, accordingly.
9	Each "Project Guide" may be assigned **maximum** 5 students.
10	The original design requirements **are not essential**, although highly encouraged. Hence, normally, projects should not be repeated. The same project undertaken in recent past, by past students, should be avoided. But it is most important that, students must put his independent study efforts on the project. Thus, student should gain practical project execution knowledge about making some useful product, after he goes through all projects completion steps listed above.
11	There project report should be file bound/spiral bound/hard bound and should have following format • **Title Page/Cover page** • **Certificate endorsed by Project Guide/Supervisor, Learner Support Center Coordinator and Head** • **Declaration for followed ethical practice and non-plagiarism** • **Acknowledgement** • **Abstract of the project** • **Table of Contents** • **List of Figures** • **List of Tables** • **Chapters of Project Report –** **Chapter 1: Introduction**: Background of the project, Need for the project, Brief idea of the project, Literature review, Aims and Objectives of the project **Chapter 2: Design and Methodology:** overview of the complete project, the scientific principles involved in the design of the project, Block Diagrams, Experimental/Theoretical Methodology/Circuit/Model/ materials required, etc. **Chapter 3: Testing, Conduct of Experiment/ Module**: Actual conduct of experiment, measurements, observations, etc. **Chapter 4: Analysis of Data:** Analysis of the data and observations received during experimentation **Chapter 5: Results, Discussion and Conclusions:** Discuss why the specifications were not met or the reasons for the failure, if any. Discussed the problems and difficulties encountered and how they were / can be eliminated. Discuss any extension work or modifications, which you want to suggest.

	Chapter 6: References: List the books, reference books, journals, websites, magazines and data manuals used, etc.
12	**Project Report Submission Process**: Student should prepare 2 copies of the Project Report. At the beginning, the respective Project Guide must approve both copies positively before the end examination of Project Work. Then respective Study Center Coordinator approves both copies of the Project Report. Student should submit one of these approved copies to the study center. The student should retain remaining one of these approved copies. Study center should preserve their copy of, all project reports, till the end examination of Project Work. **Even student must bring his own copy during this end examination**.
13	**Project Report Format:** 1. **The project report should be printed on only right side of A4 size (210 mm ´ 297 mm) paper. There is no minimum or maximum page number limit for the "Project Report", but report of minimum 50–70 pages is expected. University recommends only flexible binding for the "Project Report". But, if student wishes, he may also use spiral binding.** 2. **Margins should be as follows:·** ▪ **Left Margin : 40mm** ▪ **Right Margin : 20mm** ▪ **Top Margin : 20mm** ▪ **Bottom Margin : 27mm** 3. **Header should not be used. Footer, containing page number at the center should only be used, with footer margin of 25mm.** 4. **Text should be printed in font size of 12 points and at interline distance of 18 points. (That is 1.5 line spacing). Normally, figures should be embedded in the text, where there first reference occurs. But if necessary, figures may be grouped on separate pages. Figure should be numbered as 'Fig C.F', where 'C' is chapter number and 'F' is figure number. Figure number 'F' is reset back to 1 for each new chapter.** **Page Sequence: (1) Cover page as per specimen 1 (2) Certificate page as per specimen 2 (3) Acknowledgement page for the help offered by individuals and institution (4) Content page as per specimen 3. Following suggested scheme of chapters in project report then follows these first 4pages.**

14	**Specimen of Pages** **Specimen 1** **Project Title- M.Sc. in .....** **Submitted by** **Name of Student-** **Name of Project Guide-** **Name of the Learner Support Center–** **Yashwantrao Chavan Maharashtra Open University** **20... - ...**	**Specimen 2 Certificate** This is to certify that Mr/Ms..... .....(PRN ...) has successfully completed a project entitled "..... " in partial fulfilment for the requirement of **Master of Science in .....** Signature with Date Project Guide / LSC Coordinator Internal Examiner / External Examiner

COURSE OUTCOMES

After successful completion of this course, student should be able to

- Demonstrate proficiency in designing and implementing a research project in mathematics, including formulating research questions, hypotheses, and methodologies appropriate to the chosen topic.
- Develop advanced critical thinking skills to evaluate existing literature, mathematical models, and methodologies relevant to their research topic, identifying gaps, limitations, and opportunities for further investigation.
- Contribute to the advancement of mathematical knowledge by solving novel theoretical problems, proving new mathematical theorems, or developing innovative mathematical models and algorithms.
- Acquire skills in collecting, organizing, and analyzing data using mathematical techniques, statistical methods, or computational algorithms, and interpreting results to draw meaningful conclusions.
- Communicate their research findings, methodologies, and theoretical developments effectively through scholarly writing, producing a well-structured thesis, research paper, or technical report adhering to academic standards and conventions.
- Present their research work orally to academic audiences, demonstrating the ability to articulate complex mathematical concepts, explain research methodology, and defend research outcomes during seminars, conferences, or thesis defenses.
- Uphold ethical principles and integrity in all aspects of the research process, including data collection, analysis, reporting, and dissemination, following institutional guidelines and professional standards for research ethics.

ELECTIVE COURSES

MAT613: CRYPTOGRAPHY

PROGRAMME INFORMATION

SN	Description	Details
1	University	Yashwantrao Chavan Maharashtra Open University Nashik - 422 222, Maharashtra, India Website: http://www.ycmou.ac.in/and http://ycmou.digitaluniversity.ac/
2	School	School of Sciences
3	Discipline	Science
4	Level	PG
5	Course Used in	V151: M.Sc.(Mathematics) {2023 Pattern} & V130 M.Sc.(Mathematics){2021 Pattern}

COURSE INFORMATION

Sem	Major	Code	Course Name	CR	CST	ST	CA	EE	TM	Type
04	DSE	MAT613	Cryptography	4	12	120	30	70	100	T

PRESUMED KNOWLEDGE AND LEARNING OBJECTIVES

Presumed Knowledge	Learning Objectives
For successful completion of this course, student should have successfully complete: • BSc/BA with Mathematics or equivalent from a recognized University/Board.	The objectives of this course are • To introduce various primality tests, encryption and decryption algorithms • To explain arithmetic of elliptic curves in cryptography • To study ways of doing secret communication

UNITS

UN	Name of the Unit	CSs	Questions
01-01 01-02 01-03 01-04	**Introduction to Cryptography** **Classical Ciphers** **Cryptanalysis of Classical Ciphers** **Finite Fields**	**CR 01**	As per evaluation pattern, on Each Credit, Student is required to answer • Very Short Answer Question (VSAQ), of 03 marks • Short Answer Question (SAQ), of 05 marks • Long Answer Question (LAQ) of 10 Marks (LAQ may contain sub-questions (a), (b) and so on.)
02-01 02-02 02-03 02-04	**Block Ciphers** **Pseudo-Random Bit Generator** **Linear Feedback Shift Register** **Stream Ciphers**	**CR 02**	
03-01 03-02 03-03 03-04	**Cryptographic Hash Functions** **SHA-1, SHA-2 Family** **SHA-3 and Applications** **Number Theoretic Algorithms**	**CR 03**	
04-01 04-02 04-03 04-04	**Introduction to Public Key Cryptography** **Discrete Logarithm Problem and ElGamal Cryptosystem** **Diffie-Hellman Key Exchange and RSA** **Elliptic curve Cryptography**	**CR 04**	

DETAILED SYLLABUS

UN	Detailed Syllabus of the Unit	CR
1-1	**Introduction to Cryptography**: Classifications of Cryptography, Few Applications of Cryptography, Basic Terminology, Applications of Modern Algebra and Number Theory in Cryptography - Groups and Subgroups, Rings and Fields, Number Theory	CR 01
1-2	**Classical Ciphers:** Caesar Cipher, Shift Cipher, Affine Cipher, Substitution Ciphers, Transposition Ciphers - Columnar Transposition Ciphers, Row Transposition Ciphers, Poly-alphabetic Ciphers - Vigen`ere Cipher, Hill Cipher	
1-3	**Cryptanalysis of Classical Ciphers:** Cryptanalysis of Mono-alphbetic Cipher - Cryptanalysis of the Affine Cipher, Cryptanalysis of Poly-alphabetic Cipher - Cryptanalysis of the Hill Cipher	
1-4	**Finite Fields:** Polynomial Rings, Vector Spaces, Finite Fields	
2-1	**Block Ciphers:** Modes of operations in Block ciphers, Substitution-Permutation Network Cipher - Feistel Structure for Block ciphers, Mathematical Description of Each Round in the Feistel Structure, Decryption in Ciphers Based on the Feistel Structure, Linear Cryptanalysis, Differential Cryptanalysis, DES - DES algorithm, Description of DES algorithm, AES - Application of finite fields in designing AES S-box, AES Key Expansion, Applications of finite field in MixColumns	CR 02
2-2	**Pseudo-Random Bit Generator**: Classification of Random bit generators, Famous Pseudorandom bit generators, Cryptographically secure PRBGs - NIST Statistical Test Suite, Significance of pseudo random sequence, How to check whether a pseudo random sequence is random? - Golomb's postulates, Five basic tests, Blum-Blum-Shub	
2-3	**Linear Feedback Shift Register:** LFSR Synthesis algorithm, Statistical Properties of m-sequences	
2-4	**Stream Ciphers:** Key Advantages of Stream Ciphers, Classification of stream ciphers, Mathematical expression for Perfect Secrecyin OTP, Salsa20, ChaCha stream cipher	
3-1	**Cryptographic Hash Functions:** Iterated Hash Functions, Merkle-Damgard Construction, Weaknesses in Merkle-Damgard Construction	CR 03
3-2	**SHA-1, SHA-2 Family:**SHA-0/SHA-1 Algorithm - Padding the Message, Parsing the Padded Message, Definition of Constants, Round Functions, SHA-0/SHA-1 Hash Computation, SHA-2 Hash Functions, SHA-224/SHA-256 Algorithm - Definition of Constants, Boolean Functions, SHA-224/SHA-256 Hash Computation, SHA-384 Algorithm - Padding the Message, Parsing the Padded Message, Setting the Initial Hash Value, SHA-384 Hash Computation, SHA-512 Algorithm	
3-3	**SHA-3 and Applications:**SHA-3 Competition, Keccak Algorithm, Applications of Cryptographic Hash Functions	
3-4	**Number Theoretic Algorithms:** Structure of $Z_n$and $Z_n{}^*$, Prime Numbers - Mersenne primes and Fermat numbers, Prime number Theorem, Primality testing - Deterministic algorithms for primality testing, Probabilistic algorithms for primality testing	
4-1	**Introduction to Public Key Cryptography:**The Chinese Remainder theorem, Modular exponentiation by the repeated squaring	CR 04
4-2	**Discrete Logarithm Problem and EIGamal Cryptosystem:** Algorithms to solve Discrete Log problem, ElGamal Cryptosystem with Examples	
4-3	**Diffie-Hellman Key Exchange and RSA:** RSA cryptosystem- RSA Key	

	Generation, RSA Public-key cipher, RSA Public-key cipher, Integer factorization problem (IFP), Digital Signatures,	
4-4	**Elliptic curve Cryptography:** Elliptic curves over Reals, Elliptic Curves over Finite Fields, ElGamal Cryptosystem on Elliptic Curves	

LEARNING RESOURCE DETAILS

LR Code	Title Author	Edition Year	ISBN Publisher
Course Website Link for (1) Mobile and Online Lectures, (2) Discussion Forum for online interaction and (3) Self-Test for each CR Block, Continuous Assessment Test and End Examination			
CW-MAT613			
Text-Books			
MAT613-T01	Cryptography, Dr. Dhananjoy Dey, Dr. Indivar Gupta, Mr. Harshdeep Singh	2023	978-81-19453-00-9 YCMOU
Reference-Books: Explore additional details and reinforce learning, with this optional learning resource!			
MAT613 – RB1	A Course in Number Theory and Cryptography, Neal Koblitz	1994 3rd Indian Reprint, 2008	978-81-8128-230-9, Springer
MAT613 – RB2	Cryptography Theory and Practice, Douglas Stinson	2006 3rd Indian Reprint, 2015	1-58488-508-4
MAT613 – RB3	An Introduction to Mathematical Cryptography, J. Hoffstein, J. Pipher, J. H. Silverman	2nd Ed, 2014	978-1-4939-1710-5, Springer
MAT613 – RB4	Introduction to Cryptography, J. A. Buchmann,	2001, 2nd Ed (Indian Reprint, 2005)	81-8128-232-9, Springer
CD / DVD: Explore additional details and reinforce learning, with this optional learning resource!			
MAT613 - CD1			
Web Links: Explore additional details and reinforce learning, with this optional learning resource!			
MAT613-WL1			

COURSE OUTCOMES

After successful completion of this course, student should be able to

- Use various primarily tests, encryption and decryption algorithms
- Apply arithmetic of elliptic curves in cryptography
- Use ways of doing secret communication

MAT614: Topics in Fuzzy Mathematics

Programme Information

SN	Description	Details
1	University	Yashwantrao Chavan Maharashtra Open University Nashik - 422 222, Maharashtra, India Website: http://www.ycmou.ac.in/and http://ycmou.digitaluniversity.ac/
2	School	School of Sciences
3	Discipline	Science
4	Level	PG
5	Course Used in	V151: M.Sc.(Mathematics) {2023 Pattern} & V130 M.Sc.(Mathematics){2021 Pattern}

Course Information

Sem	Major	Code	Course Name	CR	CST	ST	CA	EE	TM	Type
01	DSE	MAT614	Topics in Fuzzy Mathematics	4	12	120	30	70	100	T

Presumed Knowledge and Learning Objectives

Presumed Knowledge	Learning Objectives
For successful completion of this course, student should have successfully complete: • BSc/BA with Mathematics or equivalent from a recognized University/Board.	The objectives of this course are • To study the concepts of fuzzy sets, algebra of fuzzy sets and extension principal. • To study generalize notions of fuzzy union, intersection and fuzzy complementation and their properties. • To study application of fuzzy relations, fuzzy arithmetic's, fuzzy relation equations and fuzzy logic for real life problems

Units

UN	Name of the Unit	CSs	Questions
01-01 01-02 01-03 01-04	**Fuzzy Sets and Crisp Sets** **Convex Fuzzy Sets** **Extension Principle** **Fuzzy Complementation**	**CR 01**	As per evaluation pattern, on Each Credit, Student is required to answer • Very Short Answer Question (VSAQ), of 03 marks • Short Answer Question (SAQ), of 05 marks • Long Answer Question (LAQ) of 10 Marks (LAQ may contain sub-questions (a), (b) and so on.)
02-01 02-02 02-03 02-04	**Fuzzy Intersections and Unions** **Dual triplets and Aggregation operations** **Fuzzy Arithmetic** **Lattice of Fuzzy Numbers and Fuzzy Equations**	**CR 02**	
03-01 03-02 03-03 03-04	**Fuzzy Relations** **Fuzzy Equivalence Relations** **Composition of Fuzzy Relations** **Fuzzy Relation Equations**	**CR 03**	

04-01 04-02 04-03 04-04	**More on Fuzzy Relations Equations and Approximate Solutions** **Fuzzy Propositions** **Fuzzy Quantifiers** **Approximate Reasoning**	**CR 04**	

DETAILED SYLLABUS

UN	Detailed Syllabus of the Unit	CR
1-1	**Fuzzy Sets and Crisp Sets**: Definitions, α-cuts, Basic Operations onFuzzy Sets,cardinality, degree of subset-hood, types of fuzzy sets, Cartesian products, algebraic products bounded sum and difference.	**CR 01**
1-2	**Convex Fuzzy Sets**: Properties of α-cuts,Convex fuzzy sets, Decomposition theorems	
1-3	**Extension principle:** Image and Pre-image of fuzzy sets under crisp function, Properties with α-cuts, Extension of the principle for pair of sets	
1-4	**Fuzzy Complementation**: Definition Examples, Equilibrium and dual points with respect to fuzzy complement, Increasing and Decreasing Generators, Characterization Theorem of Fuzzy Complements, More Examples of Fuzzy Complements.	
2-1	**Fuzzy Intersections and Unions**: Definition and Examples of fuzzy intersections or t-norms, Characterization theorems for t-norms, Definition and examples of fuzzy unions or t-conorms, Characterization theorems for t-conorms.	**CR 02**
2-2	**Dual Triplets and Aggregation Operations**: Dual triplets, characterization theorems for dual triplets, Aggregation operations and their properties.	
2-3	**Fuzzy Arithmetic**: Fuzzy Numbers, Types of Fuzzy Numbers, Elements of fuzzy arithmetic, Interval arithmetic, sum, difference, multiplications of fuzzy numbers, Lattice of fuzzy numbers.	
2-4	**Lattice of Fuzzy Numbers and Fuzzy Equations:** Maximum and Minimum of fuzzy numbers, Ordering on fuzzy numbers, Equations of the type $A + X = B$ *and* $A \cdot X = B$ with A, B are fuzzy numbers.	
3-1	**Fuzzy Relations**: Fuzzy Relations, Binary fuzzy relations, Composition of fuzzy relations, Max-min closure and its extension.	**CR 03**
3-2	**Fuzzy Equivalence Relations:** Definition and examples, Fuzzy computability relations, Fuzzy ordering.	
3-3	**Composition of Fuzzy Relations:** sup-t composition of fuzzy relations, inf-ω_i compositions, relation betweensup-t and inf-ω_i compositions of fuzzy binary operations.	
3-4	**Fuzzy Relation Equations:** max-min relation equations, sup-t relation equations.	
4-1	**More Fuzzy Relations Equations and Approximate Solutions**: inf-ω_i relation equations, Approximate solutions of fuzzy relation equations, Equality and solvability indices.	**CR 04**
4-2	**Fuzzy Propositions:** Unconditional and unqualified fuzzy propositions, Unconditional and qualified fuzzy propositions, Conditional and unqualified fuzzy propositions, Conditional and qualified fuzzy propositions, Truth values of compound fuzzy propositions.	
4-3	**Fuzzy Quantifiers**: Fuzzy Quantifiers, Linguistic hedges, Inference from conditional fuzzy propositions, Inference from conditional and qualified fuzzy	

	propositions, Inference from quantified fuzzy propositions.	
4-4	**Approximate Reasoning:** Fuzzy Implications Definition and examples, Types of fuzzy propositions, Selection of fuzzy implications, Multi conditional approximate reasoning, Role of fuzzy relational equations.	

LEARNING RESOURCE DETAILS

LR Code	Title Author	Edition Year	ISBN Publisher
Course Website Link for (1) Mobile and Online Lectures, (2) Discussion Forum for online interaction and (3) Self-Test for each CR Block, Continuous Assessment Test and End Examination			
CW-MAT614			
Text-Books			
MAT614-T01	Topics in Fuzzy Mathematics, Prof. S. R. Chaudhari	2023	978-81-19453-01-6 YCMOU
Reference-Books: Explore additional details and reinforce learning, with this optional learning resource!			
MAT614 – RB1	Fuzzy Sets and Fuzzy Logic Theory and Applications, George J. Klir, Bo Yuan,	2000	PHI, Ltd. 0-13-101171-5
MAT614 – RB2	Fuzzy Logic with Engineering Applications, T. J. Ross,	2010	McGraw Hill, International Editions,
MAT614 – RB3	Fuzzy Sets Theory- and its Applications, H J Zimmermann	1985	Springer
CD / DVD: Explore additional details and reinforce learning, with this optional learning resource!			
MAT614 - CD1			
Web Links: Explore additional details and reinforce learning, with this optional learning resource!			
MAT614-WL1			

COURSE OUTCOMES

After successful completion of this course, student should be able to

- Apply the concepts of fuzzy sets, algebra of fuzzy sets and extension principal.
- Explain generalize notions of fuzzy union, intersection and fuzzy complementation and their properties.
- Apply fuzzy relations, fuzzy arithmetic's, fuzzy relation equations and fuzzy logic for real life problems.

MAT615: ALGEBRAIC TOPOLOGY

PROGRAMME INFORMATION

SN	Description	Details
1	University	Yashwantrao Chavan Maharashtra Open University Nashik - 422 222, Maharashtra, India Website: http://www.ycmou.ac.in/and http://ycmou.digitaluniversity.ac/
2	School	School of Sciences
3	Discipline	Science
4	Level	PG
5	Course Used in	V151: M.Sc.(Mathematics) {2023 Pattern}

COURSE INFORMATION

Sem	Major	Code	Course Name	CR	CST	ST	CA	EE	TM	Type
04	DSE	MAT615	Algebraic Topology	4	12	120	30	70	100	T

PRESUMED KNOWLEDGE AND LEARNING OBJECTIVES

Presumed Knowledge	Learning Objectives
For successful completion of this course, student should have successfully complete: • BSc/BA with Mathematics or equivalent from a recognized University/Board.	The objectives of this course are to • Know the concept of Geometric complexes and simplicial homology • Study simplicial approximations • Know the homotopic paths and fundamental groups • Apply discrete, algebraic methods to solve topological problems

UNITS

UN	Name of the Unit	CSs	Questions
01-01 01-02 01-03 01-04	Introduction of vector spaces Geometric complexes and polyhedra Orientation of Geometric complexes Chains, Cycles, Boundaries, Homology groups	CR 01	As per evaluation pattern, on Each Credit, Student is required to answer • Very Short Answer Question (VSAQ), of 03 marks • Short Answer Question (SAQ), of 05 marks • Long Answer Question (LAQ) of 10 Marks (LAQ may contain sub-questions (a), (b) and so on.)
02-01 02-02 02-03 02-04	The structure of homology groups The Euler-Poincare theorem Pseudo-manifolds, Fundamental group of S^n Simplicial approximation theorem	CR 02	
03-01 03-02 03-03 03-04	Introduction to topological spaces Homotopy between continuous functions and Homotopy equivalence Homotopic paths and Fundamental groups Covering spaces	CR 03	
04-01 04-02 04-03 04-04	Covering homotopy property of S^1 Examples of Fundamental groups Relation between first homology group and fundamental group The Brouwer's fixed point theorem	CR 04	

DETAILED SYLLABUS

UN	Detailed Syllabus of the Unit	CR
1-1	**Introduction of vector spaces**: Vector spaces, subspaces, basis, dimension.	CR 01
1-2	**Geometric complexes and polyhedra:** Geometrically independent set, simplexes, Barycentric co-ordinates, faces, Geometric complex, r-skeleton.	
1-3	**Orientation of Geometric complexes:** Oriented simplexes, Oriented complexes, incidence number.	
1-4	**Chains, Cycles, Boundaries, Homology groups:** p-chain, elementary p-chain, boundary map, p-homology group.	
2-1	**The structure of homology groups:** Connected simplex, connected complex and the structure of homology groups for connected complexes.	CR 02
2-2	**The Euler-Poincare theorem:** Betty number, Euler characteristic, The Euler-Poincare theorem, Euler's theorem.	
2-3	**Pseudo-manifolds, homology group of S^n:** n-pseudo-manifold, orientablen-pseudo-manifold, homology group of S^n.	
2-4	**Simplicial approximation theorem:** Simplicial map, star of vertex, simplicial approximation to continuous function, Simplicial approximation theorem.	
3-1	**Introduction to topological spaces:** Topological space, T_0, T_1 and T_2 (Hausdorff's) spaces, continuous function, Pasting lemma, connected spaces.	CR 03
3-2	**Homotopy between continuous functions and Homotopy equivalence:** Homotopy between continuous functions, Homotopy equivalence, contractible spaces.	
3-3	**Homotopic paths and Fundamental groups:** Paths, loops, product of two paths, reverse path, homotopy between paths, Fundamental group, simply connected spaces.	
3-4	**Covering spaces:** Covering spaces and its basic properties.	
4-1	**Covering homotopy property of S^1:** Covering path property, generalized covering path property, covering homotopy property, generalized covering homotopy property, degree of a path.	CR 04
4-2	**Examples of Fundamental groups:** Fundamental group of S^1, torus, closed cylinder, contractible spaces, Van-Kampen theorem.	
4-3	**Relation between first homology group and fundamental group:** Relation between first homology group and fundamental group	
4-4	**The Brouwer's fixed point theorem:** Brouwer's no retraction theorem and Brouwer's fixed point theorem, The Brouwer-Poincare theorem.	

LEARNING RESOURCE DETAILS

LR Code	Title Author	Edition Year	ISBN Publisher
Course Website Link for (1) Mobile and Online Lectures, (2) Discussion Forum for online interaction and (3) Self-Test for each CR Block, Continuous Assessment Test and End Examination			
CW-MAT615			
Text-Books			
MAT615-T01			
Reference-Books: Explore additional details and reinforce learning, with this optional			

learning resource!			
MAT615 – RB1	Basic concepts of algebraic topology, F. H. Croom	Second 1978	0-387-90288-0 Springer-Verlag New York
MAT615 – RB2	Lecture notes on elementary topology and geometry, I. M. Singer and J. A Thorpe	Second 1967	0-387-90202-3 Springer-Verlag New York
MAT615 – RB3	Algebraic Topology, Hatcher, A.	2002	Cambridge University Press
MAT615 – RB4	An Introduction to Algebraic Topology, Text in Mathematics, No. 119, Rotman, J. J	2004	Springer, New York.
CD / DVD: Explore additional details and reinforce learning, with this optional learning resource!			
MAT615 - CD1			
Web Links: Explore additional details and reinforce learning, with this optional learning resource!			
MAT615-WL1			

COURSE OUTCOMES

After successful completion of this course, student should be able to

- Explain the fundamental concepts of algebraic topology and their role in modern mathematics and applied contexts.
- Explain the well-known theorems- The Euler-Poincare theorem, Euler's theorem, Brouwer's fixed point theorem.
- Learn the relation between first homology group and fundamental group.
- Apply problem-solving using algebraic topology techniques applied to diverse situations in physics, engineering and other mathematical contexts.

END OF DOCUMENT