MIPA UGM
Research for Innovations

CURRICULUM 2022

MASTER'S PROGRAMME IN MATHEMATICS

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CHAPTER 1 FACULTY

1.1 INTRODUCTION

The Faculty of Mathematics and Natural Sciences at Universitas Gadjah Mada (UGM) was officially established on September 19, 1955, through the Decree of the Minister of Education, Teaching, and Culture dated September 15, 1955, with the number 53759/Kab. In this decree, the faculty was still a combined faculty with the Faculty of Engineering, referred to as the Union of Exact Sciences and Engineering Faculties. Starting from September 1, 1956, the Faculty of Exact Sciences and Natural Sciences (abbreviated as FIPA) began to separate from the Faculty of Engineering.

At the time of its establishment as a Union Faculty, FIPA had only one department called the Exact Sciences Department, which had existed since 1950 as a department within the Civil Engineering Department of the Faculty of Engineering. When FIPA began to operate as an independent faculty on September 1, 1956, a new department was opened, initially called the Natural Sciences Department. Then, on September 1, 1960, another department was added, which was the Chemistry Department. On December 28, 1982, the name FIPA was changed to FMIPA (Faculty of Mathematics and Natural Sciences or FMNS), and it had three departments: Physics, Chemistry, and Mathematics.

From its time as a combined faculty until its separation from the Faculty of Engineering, the office and teaching activities were conducted in the old Faculty of Engineering building located at Jetisharjo street Number 1, Yogyakarta. Basic physics laboratory activities were still held in the Faculty of Medicine complex in Mangkubumen.

Until 1986, the Faculty of Mathematics and Natural Sciences had physical infrastructure with a building area of 13,925 m^2 and a library with 10,529 books and 4,297 book titles. In 1987, with the assistance of World Bank Project IX, the library facilities were expanded to 13,929 books with 5,954 book titles, and the physical building infrastructure was increased by 1,369 m2 for faculty office rooms and 3,764 m^2 for the chemistry laboratory building, totalling 19,058 m^2.

With the construction of the faculty administration building and the chemistry laboratory building in Sekip Utara by the World Bank Project IX, the FMNS Administrative Office, Department of Physics, and Department of Chemistry started to occupy the new building area in Sekip Utara in February 1989. In February 1994, a fire incident occurred in Sekip Unit III building. Approximately one-third of the building, approximately 1,200 m^2, was severely damaged and could no longer be used. All the Organic Chemistry laboratory spaces, Computational laboratory, and the Postgraduate Mathematics Library, along with all its contents, including laboratory equipment, practical and research materials, books, magazines, journals, and other items, were destroyed in the fire.

At the beginning of the 1995/1996 academic year, a new building for the Department of Physics had been completed, although it was only a part of the original plan. Meanwhile, the construction of new buildings for the Department of Mathematics and the Department of Chemistry had also begun. By early 1996, most of the construction of the new buildings had been completed, and all administrative and academic activities were already located in Sekip Utara.

In early 2003, a three-story building with an area of 1,506.90 m^2 was completed, increasing the total building area to 22,552 m^2. This new building was used for lectures, the Computer Laboratory, and the Student Internet Centre.

The Master's program initially only covered the fields of Physics and Chemistry, starting from the academic year 1992/1993, and was expanded to include the field of Mathematics in accordance with DIKTI Decree Number 128/DIKTI/Kep/1992. The Physics field included a focus on geophysics. For the Mathematics field, a computer science focus was introduced on April 11, 1992. Then, in the academic year 1999, the Faculty of Mathematics and Natural Sciences (FMNS) also established a Master's program in Computer Science under DIKTI Decree Number 259/DIKTI/KEP/1999, dated May 27, 1999.

In 2010, the proposal for the establishment of the Department of Computer Science and Electronics (Jurusan Ilmu Komputer dan Elektronika or JIKE), which had been submitted by the faculty since 2006, was finally approved by UGM. In the organizational structure, JIKE oversees two undergraduate programs: Electronics and Instrumentation, which moved from the Physics Department, and Computer Science, which moved from the Mathematics Department. Additionally, there are Master's and Ph.D. programs in Computer Science.

In order to streamline and optimize the performance of all units within the Faculty of Mathematics and Natural Sciences at UGM to expedite the realization of the faculty's vision and mission, a new organizational structure (SOTK) was established for the Faculty of Mathematics and Natural Sciences at UGM through Rector UGM Decree Number 809/P/SK/HT/2015. In Article 28 of this decree, the term "Departemen" is used as the unit under the faculty to replace "Jurusan". Furthermore, through Decree Number 580/UN1.P/KPT/HUKOR/2022, the UGM Rector established a specific SOTK for the Faculty of Mathematics and Natural Sciences at UGM, as indicated in **Figure 1.1.**

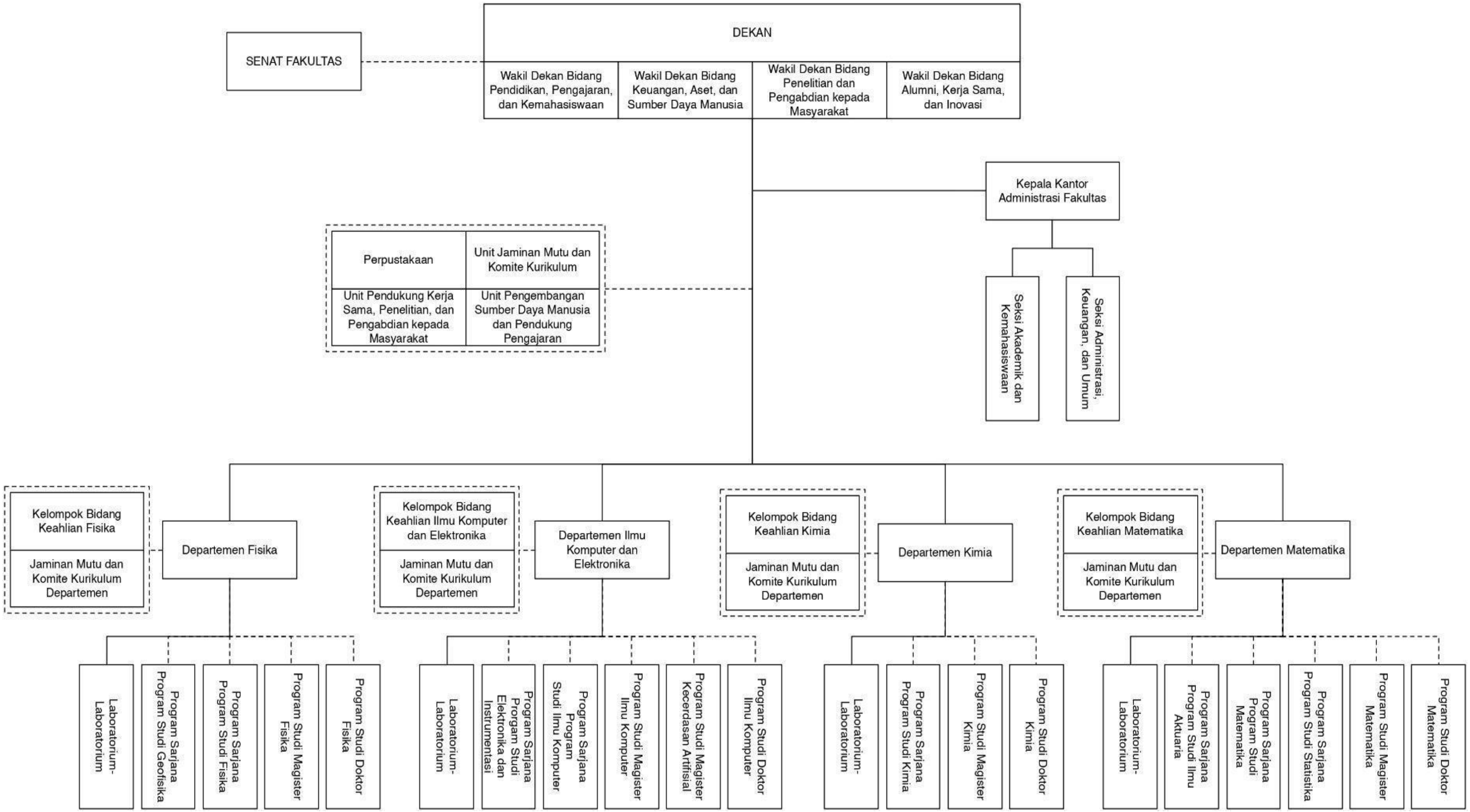

Figure **Error! No text of specified style in document.**.1 SOTK FMNS UGM

In order to fulfill the mandate it carries, the Faculty of Mathematics and Natural Sciences at UGM adheres to and follows the Core Values established by the university, as outlined in the Strategic Plan Document of Universitas Gadjah Mada for the period 2018-2022. These core values are as follows:

1. **Pancasila Values**: These encompass the values of divinity, humanity, unity, democracy, and justice.
2. **Scientific Values**: These include the principles of the universality and objectivity of knowledge, academic freedom and the academic pulpit, recognition of facts and truths for the sake of civilization, and usefulness and happiness.
3. **Cultural Values**: These embrace tolerance, human rights, and diversity.

1.2 VISION

The vision of the Faculty of Mathematics and Natural Sciences (FMNS) at UGM, as stated in the Strategic Plan and Operational Plan (Renstra and Renop) of FMNS UGM 2018-2022, is to become a nationally excellent and internationally leading faculty by the year 2037. It aims to develop mathematics, physics, chemistry, as well as computer and electronics science for the prosperity of the nation, guided by the cultural values of the nation based on Pancasila.

1.3 MISI

The mission of the Faculty of Mathematics and Natural Sciences (FMNS) at UGM, as stated in the Strategic Plan and Operational Plan (Renstra and Renop) of FMNS UGM 2018-2022, includes the following objectives:

1. Develop internationally competitive education in the fields of mathematics, physics, chemistry, computer science, and electronics by maximizing research outcomes.
2. Conduct outstanding, innovative, and targeted research in the fields of mathematics, physics, chemistry, computer science, and electronics for the welfare of the nation and humanity at large.
3. Serve the community by utilizing research outcomes in the fields of mathematics, physics, chemistry, computer science, and electronics to address national and global challenges.
4. Continuously develop resources, organization and governance, and supporting facilities in a sustainable manner.

1.4 OBJECTIVE

The objectives to be achieved are the realization of the Faculty of Mathematics and Natural Sciences (FMNS) UGM as part of Universitas Gadjah Mada to become an outstanding faculty in Indonesia with international achievements and reputation through:

1. **Excellence and Innovative Education:** Providing internationally competitive education in the fields of Mathematics, Physics, Chemistry, Computer Science, and Electronics, characterized by cross-disciplinary content, innovation, soft skills, and state-of-the-art information technology. This includes postgraduate programs as the backbone in producing graduates who are healthy, virtuous, confident, competitive, innovative, entrepreneurial, and responsible towards the nation.
2. **Outstanding, Innovative, and Targeted Research:** Conducting research in Mathematics, Physics, Chemistry, Computer Science, and Electronics that is environmentally conscious, nationally and internationally recognized, and capable of providing solutions to national and global challenges. This research should be based on the excellence of human and natural resources and local wisdom, involving stakeholders in accordance with the faculty's research master plan.
3. **Outstanding and Innovative Community Engagement:** Engaging with the community based on expertise in the fields of Mathematics, Physics, Chemistry, Computer Science, and Electronics. This includes contributions to the community through knowledge, appropriate technology, and advocacy in these fields, promoting self-reliance and sustainable well-being. It also involves making the campus a platform for applying science and technology innovations for the community and implementing product development management systems to support the commercialization of research outcomes.
4. **Resource Development, Organizational Governance, and Equitable Collaboration:** Developing resources, organization, governance, and collaboration that are fair, transparent, participatory, and accountable to support the effectiveness and efficiency of resource utilization. This is based on an integrated information technology system to facilitate adaptive learning processes in the era of Industry 4.0.

1.5 TARGETS AND ACHIEVEMENT STRATEGIES

Targets and Achievement Strategies for Objective 1

Objective 1: Excellent and Innovative Education in the fields of Mathematics, Physics, Chemistry, Computer Science, and Electronics, characterized by cross-disciplinary content, innovation, soft skills, and state-of-the-art information technology, with postgraduate programs as the backbone in producing graduates who are healthy, virtuous, confident, competitive, innovative, entrepreneurial, and responsible towards the nation.

Table 1.1. Targets and Achievement Strategies for Objective 1

Targets	Achievement Strategies
1. Enhancing the quality of the new student admission system based on academic ability, diversity, self-reliance, and inclusivity.	1.1 Strengthening the proportion of new students through affirmative action and financial aid programs (Bidikmisi), achievements, and collaborations.
	1.2 Strengthening strategies and promotion systems for the admission of international students.
2. Creating and improving a culture of quality education and learning processes.	2.1 Enhancing the curriculum based on outcome-based education, KKNI (National Qualifications Framework), and SN-DIKTI (Higher Education Data and Information System).
	2.2 Reinforcing e-learning and Massive Open Online Courses (MOOC) for learning.
	2.3 Disseminating knowledge to enhance external learning resources through knowledge channels and knowledge towers.
	2.4 Strengthening institutional mentoring and career counseling for new students and graduates.
	2.5 Enhancing physical and non-physical education and learning infrastructure.
	2.6 Improving student achievements at the national and international levels.
	2.7 Strengthening online-based student services (Student Information System, library services, and others).
	2.8 Enhancing the quality of study programs.
3. Developing interdisciplinary education and learning as well	3.1 Developing interdisciplinary courses (IDC) based on cross-disciplinary synergy, cross-

Targets	Achievement Strategies
as exposure to global competencies.	degree programs, and cross-faculty collaboration.
	3.2 Developing courses to enhance global competency (Global Competency Exposure Courses) to improve student competencies.
4. Making postgraduate education the backbone of Higher Education's Tri Dharma (teaching, research, and community service).	4.1 Improving the quality of student research through participation in faculty research.
	4.2 Increasing the number of scholarships for postgraduate students (domestic and international).
	4.3 Increasing the number of student mobility opportunities for postgraduate students.
5. Internationalization of study programs.	5.1 Developing a visiting professor program.
	5.2 Developing Massive Open Online Courses (MOOC) in collaboration with foreign universities.
	5.3 Expanding double degree programs, dual degree programs, and twinning programs with leading foreign universities.
6. Fostering the spirit of innovation and social entrepreneurship among students.	Developing soft skills, character, and entrepreneurial spirit.
7. Promoting a healthy lifestyle among students.	Providing education on healthy lifestyles to students.

Targets and Achievement Strategies for Objective 2

Objective 2: Research in the fields of Mathematics, Physics, Chemistry, as well as Computer Science and Electronics that is outstanding, innovative, and directed, i.e., research in these fields with an environmental perspective, serving as a national and international reference, and capable of providing solutions to the issues facing the nation and humanity, based on human and natural resource excellence, and local wisdom, involving stakeholders in accordance with the faculty's research master plan.

Table Error! No text of specified style in document.**1**. **Targets and Achievement Strategies for Objective 2**

Sasaran	Strategi Pencapaian
1. Developing multidisciplinary research with an environmental perspective and local excellence values to provide solutions to societal, national, and state issues.	1.1 Developing a culture of multi, inter, and cross-disciplinary research based on the Social Humanities, Agriculture, Health, and/or Science and Technology clusters through Faculty, School, and Study Center institutions.
	1.2 Advancing comprehensive research (across various aspects) on maritime-archipelagic nations.
2 Advancing innovative research based on cultural wisdom that strongly impacts the advancement of science and technology for the benefit of the nation, state, and humanity.	2.1 Increasing the number of research publications in journals.
	2.2 Expanding intellectual property, including copyrights and geographical indications based on cultural wisdom and natural resources.
	2.3 Enhancing the utilization of research outcomes for strategic policy and industry purposes.
	2.4 Improving the profile of research capacity, activities, and expertise both internally and externally.
	2.5 Increasing the number of foreign research partners.
3 Enhancing research funding capabilities by involving external stakeholders.	3.1 Enhancing the ability and competitive advantage of multi, inter, and cross-disciplinary research to support success in securing funding from national and international sources.
	3.2 Developing and enhancing sustainable strategic partnerships with research funding providers from the government, private sector, and industry.
	3.3 Modernizing and improving the integrated and sustainable capacity of research facilities and laboratories.
4 Improving research institutions and research facility capacity.	Increasing the organization of national and international seminars.

Targets and Achievement Strategies for Objective 3

Tujuan 3: Excellence and Innovative Community Engagement Based on Expertise in Mathematics, Physics, Chemistry, Computer Science, and Electronics" refers to community engagement activities grounded in scientific knowledge, appropriate technology, and advocacy in these fields. These activities aim to promote community self-reliance and well-being in a sustainable manner by leveraging the campus as a platform for applying science and technology innovations to benefit the community. Additionally, they involve implementing a product development management system to support the commercialization of research outcomes.

Table 1.3. Targets and Achievement Strategies for Objective 3

Trgets	Achievement Strategies
1. Becoming a strategic partner to the government in efforts to enhance productivity and well-being based on community-driven initiatives.	1.1 Increasing FMNS's participation in programs aligned with the DIY (Special Region of Yogyakarta) framework and Jogja Cyber Province.
	1.2 Participating in the development of remote, underdeveloped, and disadvantaged regions (3T areas) through community-based initiatives.
2 Developing the FMNS as a platform for the application of science and technology for the wider community.	Increasing the number of technology applications developed by FMNS for communication, industry, business, and government.
3 Expanding the reach and quality of community service through the development of entrepreneurship and social responsibility.	Providing training and mentoring to the community to create commercially viable products based on appropriate technology and local resources, and facilitating access to funding opportunities for SMEs through sustained improvement in community engagement activities.
4 Building synergy with alumni networks in various regions to strengthen access to community service.	Enhancing synergy between FMNS and alumni in various regions through alumni-managed community engagement activities.
5 Enhancing the role of FMNS as a source of inspiration for community service initiatives.	Expanding the reach and improving the quality of disseminating FMNS's community engagement activities.

Targets and Achievement Strategies for Objective 4

Objective 4: The development of resources, organizational structures, governance, and equitable, transparent, participatory, and accountable collaborations is essential to support the effectiveness and efficiency of resource utilization. This should be based on an integrated information technology system to facilitate adaptive learning processes in the context of Industry 4.0.

Table 1.4. Targets and Achievement Strategies for Objective 4

Targets	Achievement Strategies
Human Resources	
	1.1 Planning and recruiting faculty based on the development of academic fields.

Targets	Achievement Strategies
1. Developing a human resource recruitment system.	1.2 Planning the recruitment of educational staff based on the university's strategic objectives.
2. Developing a career advancement system for employees.	2.1 Developing employee career management.
	2.2 Enhancing the quality and competence of faculty through advanced studies and the management of functional promotions.
	2.3 Enhancing the quality and competence of educational staff.
	2.4 Developing an integrated career information system for faculty promotions and rank advancements.
3. *Implementing a Health-Promoting Faculty program.*	3.1 Improving the health of faculty and educational staff.
	3.2 Enhancing the quality of faculty canteens.
Physical Infrastructure and Environment	
4. Enhancing integration in facility management for optimal service delivery.	4.1 Integrating the management and utilization of building facilities, laboratories, green spaces, sports facilities, and parking areas for improved educational, research, and community service services.
	4.2 Providing common spaces for interaction and connectivity among academic members across departments, faculties, schools, study centers, and other units.
	4.3 Equipping facilities and their surroundings with contemporary security equipment and standard operating procedures for emergency situations.
	4.4 Providing accessible building and facility access for academicians with special needs.
Collaboration and Alumni	
5. Strengthening strategic collaborations to accelerate educational development, research outcomes, scientific and technological innovations, and cultural advancement.	5.1 Improving the quality of sustained strategic collaborations with government, private, and national industrial partners in education, research, and community service.
	5.2 Developing and improving ongoing strategic international partnerships to facilitate joint research, professor exchanges, student exchanges, summer classes, dual-degree programs, international academic exposure, and funding provision.

Targets	Achievement Strategies
6. Increasing the synergy and contribution of alumni to strengthen the three pillars of higher education (teaching, research, and community service).	Developing and enhancing strategic collaboration networks between FMNS, alumni, and Kagama (alumni association) to strengthen the role of alumni and Kagama in supporting the three pillars of higher education..
7. Developing programs to facilitate creativity and synergy between research outcomes and downstream activities or incubation.	Supporting start-up businesses initiated by academic members and/or alumni through incubation processes within FMNS.
Governance and Institutional	
8. Strengthening a service-oriented culture and achieving excellent performance through bureaucratic reform.	Enhancing the quality of excellent service systems to promote a positive work attitude, a service-oriented mindset, integrity, and professionalism among staff, as part of the implementation of Good University Governance.
9. Enhancing institutional capacity towards achieving international standards for the faculty.	9.1 Feasibility studies, preparation, and establishment of new postgraduate programs.
	9.2 Feasibility studies, preparation, and establishment of new laboratory or research field groups.

1.6 LEARNING PROCESS

A Student Admission Requirements

In order to maintain the quality of students entering the Master's program at the Faculty of Mathematics and Natural Sciences (FMNS) at UGM, a rigorous selection process is carried out from the university application to admission into the program. The selection process conducted by the university includes:

1. Grade Point Average (GPA) from the Bachelor's degree (S1) for the Regular Master's Program.

Bachelor's Degree GPA (on a scale of 4 or equivalent)	Accreditation of the Previous Program of Study
≥ 2,50	Applicants from Bachelor's or Applied Bachelor's programs accredited as "excellent" or "A"; or
≥ 2,75	Applicants from Bachelor's or Applied Bachelor's programs accredited as "very good" or "B"; or

≥ 3,00	Applicants from Bachelor's or Applied Bachelor's programs accredited as "good" or "C".

2. GPA from the Bachelor's Degree for the Master's by Research Program

Bachelor's Degree GPA (on a scale of 4 or equivalent)	Accreditation of the Previous Program of Study
≥ 3,00	Applicants must have a Bachelor's or Applied Bachelor's degree from a program accredited at least as "very good" or "B"

3. Must have a minimum score of 450 on the PAPs, TKDA PLTI, or TPA Bappenas test.
4. Must have a minimum English language proficiency score of TOEFL 400 or AcEPT 149 (or equivalent).
5. Must provide recommendations from two individuals who are familiar with the applicant.
6. Must submit a pre-research proposal.
7. Should include evidence of publications (if available).
8. Must provide a Memorandum of Understanding (MoU) or cooperation agreement with UGM for applicants applying through collaborative programs.

Each program of study has the discretion to set higher admission requirements than those mentioned above. Additionally, they may conduct subject-specific tests related to the field of study and interviews as part of their admission process.

B Learning Process Standards

Key aspects of the learning process include:

1. characteristics of the learning process, which consist of being interactive, holistic, integrative, scientific, contextual, thematic, effective, collaborative, and student-centered.
2. planning of the learning process, which is developed for each course and presented in the semester learning program plan (rencana program kegiatan pembelajaran semester or RPKPS).
3. implementation of the learning process, where each course is conducted according to the rpkps with its respective characteristics.

4. student workload, where one credit (SKS) is equivalent to 170 (one hundred seventy) minutes of learning activities per week per semester. a semester is the unit of time for effective learning activities over 16 (sixteen) weeks.

In the learning process, each Master's program is given the flexibility to design, establish, conduct, evaluate, and develop teaching methods that essentially possess the following characteristics:

a. capable of developing logical, critical, systematic, and creative thinking through scientific research, design creation, or artistic work in the field of science and technology while considering and applying humanistic values in accordance with their expertise. They should be able to formulate scientific concepts and research findings based on scientific principles, procedures, and ethics, in the form of a thesis or equivalent, and upload it to the university's website. additionally, they should publish papers in accredited scientific journals or be accepted in international journals;
b. able to perform academic validation or studies in their respective fields of expertise to solve relevant problems in society or industry through the development of knowledge and expertise;
c. capable of formulating ideas, thoughts, and scientific arguments responsibly and based on academic ethics. they should be able to communicate these ideas through various media to the academic community and the public;
d. able to identify the field of study that is the subject of their research and position it within a research framework developed through interdisciplinary or multidisciplinary approaches;
e. capable of making decisions in the context of solving problems in the development of science and technology, while considering and applying humanistic values, based on analytical or experimental studies of information and data;
f. capable of managing, developing, and maintaining a network of colleagues and peers within the institution and the wider research community;
g. able to enhance their learning capacity independently;
h. capable of documenting, storing, securing, and retrieving research data to ensure its authenticity and prevent plagiarism.

All lecturers teaching in the Master's program must hold a Doctorate in a relevant field and have a minimum functional lecturer position.

C Semester Credit System

1. 1 (one) credit in the learning process through lectures, tutorials, or discussions consists of:
   a. 50 (fifty) minutes of face-to-face activities per week for one semester.
   b. 60 (sixty) minutes of structured assignment activities per week for one semester.
   c. 60 (sixty) minutes of independent study activities per week for one semester.
2. 1 (one) credit in the learning process through seminars or similar activities consists of:
   a. 00 (one hundred) minutes of face-to-face activities per week for one semester.
   b. 70 (seventy) minutes of independent study activities per week for one semester.
3. 1 (one) credit in the learning process through laboratories, studio work, workshops, fieldwork, research, community service, or similar activities is equivalent to 170 (one hundred seventy) minutes per week for one semester.

D Study Load

The duration and study load for the Master's education program at FMNS UGM refer to the Minister of Research, Technology, and Higher Education Regulation Number 44 of 2015, the Rector of Universitas Gadjah Mada Regulation Number 11 of 2016, and the Minister of Education and Culture Regulation Number 3/2020 on SN-Dikti, as follows:

1. The curriculum is designed for students to complete their Master's studies in 2 (two) years.
2. If a student is unable to complete their studies within 2 (two) years, they are given the opportunity to extend their studies for an additional 1 (one) semester after receiving a recommendation from their thesis advisor. The study period can be extended for another 1 (one) semester with a letter of approval from the thesis advisor indicating that the student can complete their studies within the next semester.
3. After an evaluation by the program's administrators, the first warning letter (SP 1) will be issued at the end of the 4th semester, SP 2 at the

beginning of the 6th semester, and SP 3 at the beginning of the 8th semester.

4. If a student cannot complete their studies within 4 (four) years, they are required to withdraw from the Master's program at FMNS UGM.

The total study load for a Master's student at FMNS UGM is a **minimum of 40 credits**, consisting of mandatory courses, elective courses, and the thesis. The student's study load for each semester is determined at the beginning of the semester through consultation with the Academic Advisor (Dosen Pembimbing Akademik or DPA), taking into consideration the student's performance in the previous semester. The determined study load can be fulfilled by taking mandatory courses or elective courses, considering the fulfillment of prerequisite courses.

In determining a Master's student's study load for each semester, two factors are considered: the individual student's capability and the average daily study time. If a student is deemed capable of working normally for 6 - 8 hours during the day, plus an additional 2 hours in the evening, then in a week or 5 working days, the student can work for 48 - 60 hours. For the first semester, the study load for a Master's student is between 15-20 credits. The GPA in the first semester is used to determine the study load that can be taken in the following semester (semester 2) and beyond, as indicated in the following table.

MASTER'S PROGRAM	
PREVIOUS SEMESTER GPA	**MAXIMUM CREDITS ALLOWED**
≥ 3,50	20
3,00 – 3,49	17
< 3,00	12

Each program of study is allowed to establish stricter requirements than those mentioned above. The mandatory course types for students are determined by each program of study. Specifically, for students participating in the Double/Dual Degree Program, they are allowed to take a maximum of 20 credits of courses and 8 credits for the thesis starting from the first semester..

E Academic Guidance and Final Project

Each Master's student is assigned an Academic Advisor (Dosen Pembimbing Akademik or DPA), who plays a role in providing guidance to the student to ensure a smooth planning of their studies each semester. At the beginning of each semester, students need to consult with their DPA to receive academic guidance related to filling out the Course Registration Card (Kartu Rencana Studi or KRS). Additionally, students can consult with their DPA at any time to address various academic-related issues. The KRS includes all the courses that the student will take during one semester, in accordance with the applicable regulations. Academic advisors are proposed by the program of study and appointed by the faculty.

In addition to the DPA, each Master's student has 1 or 2 Thesis Supervisors (Dosen Pembimbing Tesis or DPT), who are responsible for guiding the student in the preparation of their thesis. This guidance begins with the selection of the thesis title, the preparation of the research proposal, the conduct of research, data processing, preparation of publication manuscripts, thesis writing, and thesis defense preparation. Each student is provided with a logbook to record all research activities. All thesis supervisors must hold a doctoral degree in a relevant field and have a minimum functional lecturer position (in accordance with Law Number 12 of 2012). Thesis supervisors are proposed by the program of study and appointed by the faculty.

F Academic Leave

The residency requirement for Master's students is one year after their initial registration. Any Master's student who, for some reason, cannot participate in educational activities for one semester, must apply for academic leave with the knowledge of their DPA/thesis supervisor before the start of the ongoing semester's classes. Students who do not participate in educational activities without academic leave are still considered in their study period and are still obligated to pay tuition fees (UKT).

Students may apply for academic leave for acceptable reasons after completing educational activities during the first year of their enrollment as a Master's student at FMNS UGM. Academic leave is granted for 1 (one) semester and can be extended for an additional 1 (one) semester. The total duration of academic leave for Master's students is 2 (two) semesters.

1.7 COLLABORATION PROGRAMS

Master's programs under the umbrella of Joint Degree, Double Degree, and Dual Degree programs follow the agreements outlined in the related cooperation documents. In addition to cooperative programs, the Faculty of Mathematics and Natural Sciences supports the development of Master's programs, for example, through the Fast Track program.

1.8 ASSESSMENT METHODS

A Learning Assessment Standards

Assessment reporting involves the qualification of a student's success in completing a course, expressed within the range of:

1. Letter **A** equivalent to a score of 4 (four);
2. Letter **A-** equivalent to a score of 3,75 (three point seven five);
3. Letter **A/B** equivalent to a score of 3,5 (three point five);
4. Letter **B+** equivalent to a score of 3,25 (three point two five);
5. Letter **B** equivalent to a score of 3 (three);
6. Letter **B-** equivalent to a score of 2,75 (two point seven five);
7. Letter **C** equivalent to a score of 2 (two);
8. Letter **D** equivalent to a score of 1 (one); or
9. Letter **E** equivalent to a score of 0 (zero).

The evaluation methods for course learning are conducted through, but not limited to, the following components:

a. Mid-term exams (UTS).
b. Final exams (UAS).
c. Structured assignments, both individual and group.
d. Quizzes or tests at the beginning or end of lectures.
e. Case-based learning (case-based learning).
f. Problem-based learning (problem-based learning).

B Thesis Examination

The requirements for thesis examination are determined by each program of study. Specifically, for the Master's by Research program, students should have a paper published in a reputable international journal recognized by the program of study. The thesis can consist of a proposal, research work, presentation, publication, thesis seminar, thesis manuscript, and thesis examination. The weight of each component and the mechanism for conducting the thesis examination are determined by the program of study, with a credit load range of 8 - 12 credits.

C Course Repeating and Deletion

A course is considered passed if the grade obtained is at least a C. Students who have not met the minimum GPA requirements can improve their GPA by retaking courses or taking new courses. Students are allowed to delete courses, with the rule that a maximum of 10% of the total credits of elective courses ever taken can be deleted.

D Evaluation of Study Results

The grade point average (GPA) is calculated using the following formula:

$$GPA = \frac{\sum K_i\, N_i}{\sum K_i}$$

where K_i amd N_i are the total credit hours and grade point values for course *i*, respectively.

Evaluation of study results is conducted in the first year, at the end of the study program, and at the end of the study period based on the total credits completed and the GPA obtained. A Master's student can continue their studies if they have completed a minimum of 16 credits with a minimum GPA of 3,00 within the first year.

A Master's student can be declared graduated from the Regular Master's program if they meet the following requirements:

1. Have completed the minimum required number of credits for graduation as stipulated by the respective program of study (minimum 36 credits), which includes all courses required by the program of study and the Thesis (8 credits).
2. Cumulative GPA ≥ 3,25.
3. Minimum grade of B for the final project (Thesis).
4. Have a TOEFL score of at least 450 (AcEPT 209) and a TPA/PAPS score of at least 500 (as a requirement for graduation). TOEFL/TPA (or equivalent) scores are valid for the duration of the Master's program.
5. The thesis manuscript, accompanied by a publication manuscript, has been approved by the thesis advisor and the examination committee.
6. Each publication must include the names of the thesis advisor and the UGM advisor as the corresponding authors.

A Master's student can be declared graduated from the **Master's by Research** program if they meet the following requirements:

1. Have at least 1 paper published in a reputable international journal.

2. Have completed the minimum required number of credits for graduation as stipulated by the respective program of study (minimum 36 credits), which includes all courses required by the program of study and the Thesis (8 credits).
3. Cumulative GPA ≥ 3.25.
4. Minimum grade of B for the final project (Thesis).
5. Have a TOEFL score of at least 450 (AcEPT 209) and a TPA/PAPS score of at least 500 (as a requirement for graduation). TOEFL/TPA (or equivalent) scores are valid for the duration of the Master's program.
6. The thesis manuscript, accompanied by a publication manuscript, has been approved by the thesis advisor and the examination committee.

Graduation distinctions for **Master's by Research and Regular** Master's programs are as follows:

a. Graduates with a GPA > 3,75 and a maximum study period of 5 semesters (30 months) receive the "Cumlaude" distinction (with honors).
b. Graduates with a GPA in the range of 3,51 to 3,75 receive the "Sangat Memuaskan" (Very Satisfactory) distinction.
c. Graduates with a GPA in the range of 3,25 to 3,50 receive the "Memuaskan" (Satisfactory) distinction.

Publication requirements for **Master's by Research** program students are as follows:

a. Must have produced at least 1 (one) publication accepted in a reputable international scientific journal or have produced 2 (two) publications accepted in reputable international seminar/conference proceedings.
b. The publications can include review articles derived from research related to the thesis topic and do not necessarily have to be as the first author.
c. Each publication must include the names of the thesis advisor and the UGM advisor as the corresponding authors.

1.9 FACILITIES AND INFRASTRUCTURE

In general, the facilities for conducting the teaching and learning process, reference books, and laboratory equipment are already sufficient. The availability and adequacy of facilities for conducting world-class research publications for Materials Sciences, Computational Sciences, Mathematics, Chemistry, Computer Science, and Physics are excellent. This can be seen from the types of equipment available in each research laboratory (laboratory equipment such as TEM 120 kV, XR Diffractometer, FTIR, and UV Reflectance, X-ray tomography, etc., as well as hardware and computational programs such as Ferrari computers, Wx Maxima, Miktek, etc.).

The indicator of sufficiency is reflected in the number of international publications that have been successfully conducted and the establishment of research cooperation forums both from institutions within or outside the country. The system needed to maintain and utilize this equipment has already been established, so financially and intellectually, the equipment has high sustainability and can be self-sustaining. In addition, laboratory facilities and service institutions within the UGM environment can be easily accessed for the research needs of all undergraduate, master's, and doctoral students. These laboratories and institutions include the Research and Integrated Service Laboratory (LPPT), the Data and Information Source Centre (PSDI), formerly known as the Information and Communication Technology Service Centre (PPTIK), INHERENT Project, Postgraduate Library, and others.

For the purpose of exploratory research in various fields of interest to faculty members, the availability and sufficiency of equipment, as outlined above, are already very good. However, it is not denied that for the specific international publication needs in certain fields such as synthesis, analysis, etc., assistance from analytical services, either using equipment from other institutions in Indonesia or abroad, is still required by utilizing advanced equipment as a strength for collaborative research with the principle of mutual symbiosis. In the same way, the leading research equipment available at FMNS UGM can be used by universities throughout the country or other institutions in need. The challenge faced in the process of renewing and adding new equipment lies in the high cost of the equipment. Efforts have been made to obtain funding from DIKTI and grants from abroad.

The availability of classrooms, laboratories, faculty rooms, and research rooms is relatively very good. In 2012, the S2/S3 building with a total building area of 3,750 m^2 was completed with funds from the community, costing around 21 billion rupiahs. The main focus of this building is to facilitate rooms and laboratory equipment for master's and doctoral students, as well as lecture rooms for undergraduate programs. Since August 2012, this building has been used to support the teaching process for undergraduate, master's, and doctoral programs at FMNS UGM. This five-story building is used jointly by the Department of Chemistry (1st floor), Department of Physics (2nd floor), Department of Mathematics (3rd floor), Department of Computer Science and Electronics (4th floor), and shared facilities managed by the faculty (5th floor).

In order to meet national standards, in 2015, a Integrated Lecture Building (Library, seminar rooms, classrooms, and offices) was constructed with an approximate area of 6,000 square meters, funded with a total of around 50 billion Indonesian Rupiah sourced from the national budget (APBN). It was officially inaugurated on May 11, 2016, and has been utilized for the first semester of the academic year 2016/2017. In 2021, the Phase II of the Integrated Lecture Building was constructed, involving a cost of approximately 63 billion Indonesian Rupiah funded by the community.

1.10 Academic Quality Assurance

In order to ensure the implementation of education at FMNS UGM to realize the Vision and Mission of FMNS UGM, Goals, and Objectives that meet established quality standards, FMNS conducts the following agenda:

1. Develop a long-term program plan for FMNS UGM that always refers to the Strategic Plan (RENSTRA) of FMNS UGM for the years 2003-2007, 2008-2012, 2013-2017, and subsequently continued as RENSTRA 2017-2022, which has received approval from the Faculty Senate. In its implementation, the points of the RENSTRA are translated into Operational Plans (RENOP) and annual programs in the form of Annual Performance Plans (RKT) and Annual Activity and Budget Plans (RKAT), along with quality standards for implementation.
2. Monitor and evaluate the process of education implementation. The monitoring mechanism is carried out by the Department and study program management through the establishment of the Academic Activity Coordination Team (TK2A) at the department or study program level, as well as the Semester Coordination Team (TKS) within the study program.

To ensure the implementation of the above two points, the Quality Assurance Unit (UJM) has been established at FMNS UGM based on Rector's Decree No. 1619/P/SK/HT/2015. UJM is responsible for the implementation of the Internal Quality Assurance System (SPMI) at the faculty level. SPMI is a systematic activity of higher education quality assurance by the faculty to oversee the provision of higher education by the faculty itself in a sustainable manner. Oversight means "planning," "implementation," "control," and "development/improvement" (PPEPP) of quality standards for higher education as consistently and sustainably determined by the university for stakeholder satisfaction. SPMI is carried out to achieve:

i. compliance with academic policies, academic standards, academic regulations, and academic quality manuals,

ii. assurance that graduates have competencies as determined by each study program,

iii. assurance that each student has a learning experience according to the specifications of the study program, and

iv. relevance of education and research programs to the demands of society and other stakeholders..

In this Internal Quality Assurance System (SPMI), UJM, together with KJM, conducts periodic (annual) internal audits of doctoral study programs to evaluate, correct, and continuously improve. The implementation of SPMI as a form of sustainable quality improvement at the study program level can be presented in the following scheme.

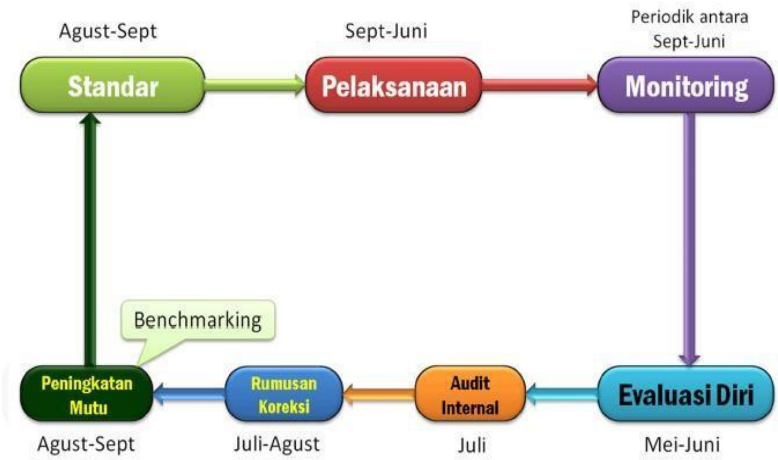

Figure 1.5. Implementation Scheme of Academic Quality Assurance (SPMI)

From the scheme above, it is evident that the faculty-level SPMI cycle can evaluate the implementation of education in accordance with quality standards and promote the continuous improvement of Master's degree programs in FMNS UGM.

1.11 Transitional REGULATIONS

1. The 2022 Curriculum for the Master's Program will be implemented starting from the first semester of the academic year 2022/2023 and will be applicable to students from the 2022/2023 cohort onwards. For students from previous cohorts, they will follow the transitional regulations specified by their respective program of study.
2. All courses that have been completed in the old curriculum will still be recognized with the credits associated with those courses.
3. Any matters that have not been addressed in these transitional regulations will be accommodated or regulated at the level of the UPPS (Study Program Work Unit) or the respective program of study.

CHAPTER 2 DEPARTMENT OF MATHEMATICS

2.1 Introduction

A Profile

The Department of Mathematics, Faculty of Mathematics and Natural Sciences at Universitas Gadjah Mada (UGM), which is celebrating its 67th anniversary in 2022, has a rich history in offering various mathematics-related study programs in Indonesia. Currently, the Department of Mathematics has produced thousands of graduates, including bachelor's degrees in mathematics and statistics, master's degrees in mathematics, and doctorates in mathematics. These graduates are spread across different regions and play active roles in various sectors within Indonesia, including industry, government, and academia.

Historically, on September 19, 1955, the Faculty of Mathematics and Natural Sciences was established at UGM under the decree of the Minister of Education, Teaching, and Culture Number 53759/Kab dated September 15, 1955. The decree mentioned that the faculty was initially combined with the Faculty of Engineering and was named the Union of the Faculty of Exact Sciences and the Faculty of Engineering. At that time, the Faculty of Exact Sciences and Natural Sciences had only one section, which was the Exact Sciences (Mathematics) section. One year later, starting from September 1, 1956, the Faculty of Exact Sciences and Natural Sciences (abbreviated as FIPA) began to separate from the Faculty of Engineering.

In 1982, the Indonesian government, through Presidential Decree Number 53 of 1982, decided to standardize the names of faculties in higher education institutions across the country. As a result, on December 28, 1982, the Faculty of Exact Sciences and Natural Sciences at UGM changed its name to the Faculty of Mathematics and Natural Sciences (abbreviated as FMIPA).

At its inception, the Department of Mathematics had three lecturers, namely Prof. Ir. RMJT Soehakso, Prof. Drs. R. Wirasto, and Drs. RM Wasisto Suryodiningrat, M.Sc. Over the years, by the end of March 2022, the Department of Mathematics has grown to have 49 staff members, with 33 of them holding doctoral degrees, and 7 of them have attained the rank of Professor.

Currently, the Department of Mathematics offers five study programs (Prodi)

1. **Bachelor in Mathematics**
2. **Bachelor in Statistics**
3. **Bachelor in Actuarial Sciences**
4. **Master Programme in Mathematics**
5. **Doctoral Programme in Mathematics**.

The Master's Program in Mathematics was established based on the Decree of the Director-General of Higher Education Number 128/Dikti/KEP/1992 dated April 11, 1992, with the highest accreditation rating ("A") from BAN PT in four accreditation submissions. Furthermore, by BAN PT, the Master's Program in Mathematics has been equated with an "EXCELLENT" accreditation rating (Decision of BAN-PT No. 8791/SK/BAN-PT/AK-ISK/M/VI/2021).

B External Condition

The globalization of industries and the rapid development of science and technology pose challenges to the field of education in general, and to the programs under the Department of Mathematics in particular. To produce competent human resources, the educational sector requires lecturers and researchers who are competent, innovative, and capable of adapting to the latest developments in science and technology. Therefore, an educational system that can produce graduates capable of competing with the workforce from other countries is essential.

Simultaneously, the demand for academic, research, consultancy, and practitioner staff with backgrounds in Mathematics, Statistics, and Actuarial Science at the undergraduate, graduate, and doctoral levels in Indonesia is increasing rapidly. The need for expertise in these three fields has led to the development of new study programs at various universities within the country. This intensifies the competition among universities and threatens the sustainability of programs under the Department of Mathematics at UGM.

Hence, the Department of Mathematics needs to continuously enhance its quality in all aspects, including human resources, facilities and infrastructure, partnerships, research, community service, and digitalization in both academic and non-academic administration. Particularly, to support research development, there is a need to strengthen collaboration between the Department of Mathematics and experts and institutions, both domestically and internationally. Furthermore, the current trends in industry, such as the fourth industrial revolution and ongoing research, are closely related to data science, including Big Data, Machine Learning, and Artificial Intelligence. This condition increases the demand for individuals with strong logical and analytical thinking skills related to the utilization of information technology in processing big data.

On the other hand, it is undeniable that recent advancements in science and technology must be supported by fundamental sciences. One field predicted to grow rapidly in supporting the industrial sector is Artificial Intelligence (AI) supported by machine learning. This provides extensive opportunities for the application of mathematics, statistics, and actuarial science in the industrial and information technology sectors.

The various challenges, threats, and opportunities mentioned above have been mapped out by the Department of Mathematics at UGM. Taking into account the department's strengths and utilizing external opportunities, the Department of Mathematics, along with its affiliated programs, has conducted a detailed SWOT analysis and devised strategies to address these challenges and minimize the impact of each program's weaknesses. These strategies have been integrated into the Department of Mathematics' strategic plan (Renstra).

C The field of Science

Mathematics is a language that plays a dual role as both a tool for analyzing and solving various real-world problems. The field of mathematics is not always associated with numerical calculations but also involves studying logic, generalization processes, abstraction, pattern recognition, modeling, and more. Thus, mathematics plays a strategically significant role in science for problem-solving purposes. With its strategic position, the Department of Mathematics is committed to excelling in mastering theory and being proficient in applying its research results.

The potential that already exists and continues to be developed includes establishing collaborations with various faculties at UGM, as well as other institutions such as BMKG (Meteorology, Climatology, and Geophysics Agency), BPS (Statistics Indonesia), BPPT (Agency for the Assessment and Application of Technology), BIN (State Intelligence Agency), several hospitals, financial institutions, and companies. Additionally, there are collaborations with other domestic and international universities.

The Department of Mathematics provides a platform for self-development for its students, particularly in nurturing critical thinking and analytical skills through various activities conducted by each program of study. In addition to providing theoretical knowledge, the department equips students to solve real-life problems related to areas such as telecommunications, finance, banking, insurance, biology, healthcare, coding, control systems, optimization, and more.

In terms of academic fields developed, the Department of Mathematics has six laboratories: Algebra Laboratory, Analysis Laboratory, Applied Mathematics Laboratory, Statistics Laboratory, Mathematical Computing Laboratory, and Statistical Computing Laboratory. These six laboratories support the curricula of the programs under the Department of Mathematics, which include Mathematics, Statistics, Actuarial Science, Master of Mathematics, and Doctor of Mathematics programs. The Department of Mathematics at FMIPA UGM is committed to preserving both the theory and applications of mathematics, in line with UGM's commitment to safeguarding the existing body of knowledge.

2.2 VISION

The vision of the Department of Mathematics, Faculty of Mathematics and Natural Sciences, UGM, in 2037 is to be a national reference in the field of mathematics, both in innovative theory and applications, at an international level. It is dedicated to serving the interests of the nation and humanity, guided by the cultural values of the nation based on Pancasila.

2.3 MISION

The mission of the Department of Mathematics, Faculty of Mathematics and Natural Sciences, UGM, is as follows:

1. To develop innovative educational activities to enhance the quality of mathematics education.
2. To conduct and produce research for the advancement of theory and to support research in applied fields
3. To promote the role of mathematics in various other fields and in society.
4. To develop and maintain continuous resources, supporting facilities, organizational structures, governance, and collaborations.

2.4 Objective

Furthermore, the mission of the Department of Mathematics is elaborated into the department's objectives, which include educational, research, community service, resource development, organization, and collaboration objectives. The objectives to be achieved are the realization of the Department of Mathematics, as part of FMIPA UGM, as a leading entity in Indonesia with international achievements and reputation through:

1. Excellent and Innovative Education in the Fields of Mathematics, Statistics, and Actuarial Science, which is internationally oriented, interdisciplinary, and supported by advanced information technology. The graduate programs are the backbone in producing graduates who are healthy, ethical, confident, competitive, innovative, possess mature soft skills, are problem solvers, entrepreneurial, and responsible towards the nation and state.
2. Research in the Fields of Algebra, Analysis, Applied Mathematics, Statistics, Mathematical Computation, and Statistical Computation, whether in monodisciplinary, multidisciplinary, interdisciplinary, or transdisciplinary contexts, that is superior, innovative, and goal-oriented. The research culture should be environmentally conscious, serve as a national and international reference, provide solutions to national and global issues, and be based on human and natural resource

excellence as well as local wisdom. It should involve stakeholders in line with the research plans of the Department and Faculty.

3. Community Service that is excellent and innovative, based on expertise in the fields of Mathematics, Statistics, and Actuarial Science. This includes community service based on knowledge, appropriate technology, and advocacy that can encourage independence and a culture of analytical, critical, and responsible thinking. It should also promote sustainable community welfare by utilizing the campus as a platform for applying science and technology innovations and implementing product development management systems to support the commercialization of research results.
4. Development of Resources, Organization, Collaboration, and Governance that are just, transparent, participatory, and accountable. This development aims to enhance the effectiveness and efficiency of resource utilization based on an integrated information technology system to support adaptive learning processes in the context of the Fourth Industrial Revolution.

2.5 Lecturers

The Department of Mathematics has 49 (forty-nine) staff members, with 33 of them holding doctoral degrees, and 7 of them having achieved the rank of Professor. Here is a list of full time teaching staff members of the Department of Mathematics.

ALGEBRA LABORATORY

No.	Lecturer Name	Notes
1.	Prof. Dr.rer.nat. Indah Emilia Wijayanti, M.Si.	Chief
2.	Prof. Dr. Sri Wahyuni, S.U.	major
3.	Dr. Budi Surodjo, M.Si.	major
4.	Dr.rer.nat. Ari Suparwanto, M.Si.	major
5.	Dr.rer.nat. Yeni Susanti., M.Si.	major
6.	Dr. Sutopo, M.Si.	major
7.	Uha Isnaini, Ph.D.	major
8.	Dr. Aluysius Sutjijana, M.Sc.	major
9.	Iwan Ernanto, M.Sc.	major
10.	Ari Dwi Hartanto, S.Si., M.Sc.	minor
11.	Rudi Adha Prihandoko, S.Si., M.Si.	minor

ANALYSIS LABORATORY

No.	Lecturer Name	Note
1.	Atok Zulijanto, Ph.D.	Chief
2.	Prof. Dr. Supama, M.Si.	major
3.	Prof. Dr. Ch. Rini Indrati, M.Si	major
4.	Dewi Kartikasari, Ph.D.	major
5.	Hadrian Andradi, Ph.D.	major
6.	Made Tantrawan, Ph.D.	major

No.	Lecturer Name	Note
7.	Umi Mahnuna Hanung, M.Sc.	major
8.	Nur Khusnussa'adah, M.Sc.	major
9.	Sekar Nugraheni, M.Sc.	major
10.	Made Benny Wiranata P., M.Sc.	major
11.	Prof. Imam Solekhudin, Ph.D.	minor
12.	Dr. rer. nat. Lina Aryati, M.S.	minor
13.	Dr. Budi Surodjo, M.Si.	minor
14.	Dr. Fajar Adi Kusumo, M.Si.	minor
15.	Dr. Nanang Susyanto, M.Sc.	minor

STATISTICS LABORATORY

No.	Lecturer Name	Note
1.	Dr. Gunardi, M.Si.	Chief
2.	Dr. Abdurakhman, M.Si.	major
3.	Drs. Danardono, MPH., Ph.D.	major
4.	Dr. Adhitya Ronnie Effendie, M.Sc.	major
5.	Danang Teguh Qoyyimi, Ph.D.,	major
6.	Drs. Zulaela, Dipl.Med.Stats., M.Si.	major
7.	Yunita Wulan Sari, M.Sc.	major
8.	Rika Fitriani, M.Sc.,	major
9.	Rianti Siswi Utami, M.Sc.	major
10.	Rahmasari Nur Azizah, M.Sc.	major
11.	Atina Husnaqilati, M.Sc.	major
12.	Prof. Dr.rer.nat. Dedi Rosadi, M.Sc.,	minor
13.	Dr. Irwan Endrayanto A, M.Sc.	minor
14.	Dr. Nanang Susyanto, M.Sc.	minor
15.	Dr. Noorma Yulia Megawati, M.Sc.	minor
16.	Vemmie Nastiti Lestari, M.Sc.	minor
17.	Dr. Dwi Ertiningsih, M.Si.	minor
18.	Oki Almas Amalia, M.Sc.	minor

APPLIED MATHEMATICS LABORATORY

No.	Lecturer Name	Note
1.	Dr. rer. nat. Lina Aryati, M. S.	Chief
2.	Prof. Dr. Salmah, M. Si.	major
3.	Dr. Fajar Adi Kusumo, M. Si.	major
4.	Dr. Indarsih, M. Si.	major
5.	Dr. Irwan Endrayanto A, M. Sc.	major
6.	Dr. Solikhatun, M. Si.	major
7.	Dr. Nanang Susyanto, M. Sc.	major
8.	Dr. Noorma Yulia Megawati, M. Sc.	major

9.	Dr. Dwi Ertiningsih, M. Si.	major
10.	Oki Almas Amalia, S. Si., M. Sc.	major
11.	Prof. Dr. Ch. Rini Indrati, M. Si.	minor
12.	Dr. rer. nat. Ari Suparwanto, M. Si.	minor
13.	Dr. Sumardi, M. Si.	minor
14.	Dr. Adhitya Ronnie Effendie, M. Sc.	minor
15.	Prof. Imam Solekhudin, Ph. D.	minor
16.	Zenith Purisha, Ph.D.	minor

COMPUTATIONAL MATHEMATICS LABORATORY

No.	Lecturer Name	Note
1.	Prof. Imam Solekhudin, Ph.D.	Chief
2.	Dr. Sumardi, M.Si	major
3.	Zenith Purisha, Ph.D .	major
4.	Ari Dwi Hartanto, M.Sc.	major
5.	Rudi Adha Prihandoko, M.Sc.	major
6.	Ivan Luthfi Ihwani, M.Sc.	major
7.	Dr.rer.nat. Lina Aryati, M.S.	minor
8.	Dr. Fajar Adi Kusumo, M.Si.	minor
9.	Dr. Indarsih, M.Si.	minor
10.	Dr. Sutopo, M.Si.	minor
11.	Dr. Irwan Endrayanto, M.Sc.	minor
12.	Dr. Solikhatun, M.Sc.	minor
13.	Dr. Dwi Ertiningsih, M.Si.	minor

COMPUTATIONAL STATISTICS LABORATORY

No.	Lecturer Name	Note
1.	Dr. Adhitya Ronnie Effendie, M.Sc.	Chief
2.	Prof. Dr.rer.nat. Dedi Rosadi, M.Sc.	major
3.	Vemmie Nastiti Lestari, M.Sc	major
4.	Dr. Gunardi, M.Si.	minor
5.	Dr. Abdurakhman, M.Si.	minor
6.	Drs. Danardono, MPH., Ph.D.	minor
7.	Dr. Herni Utami, M.Si.	minor
8.	Drs. Zulaela, Dipl.Med.Stats.	minor
9.	Yunita Wulan Sari, S.Si., M.Sc.	minor

The part-time teaching staff members requested to teach at the Department of Mathematics are as follows:

1. Yusuf, Drs., M.A. Math.

2. Diah Junia Eksi Palupi, Dra., M.S., Dr.

In addition, there are several non-permanent instructors from other faculties at UGM or institutions outside of UGM.

2.6 OBJECTIVES AND ACHIEVEMENT STRATEGIES

The Strategic Plan (Renstra) and Operational Plan (Renop) of the Department of Mathematics for the period 2018-2022 serve as performance targets for the development of the Annual Work Plan (RKT) and as a performance evaluation tool in achieving its strategic objectives.

Table 2.1. Objectives, Indicator, and Targets Department of Mathematics in the next five years

No.	Objective	Indicator	2021 (*Baseline*)	2022	2023	2024	2025	2026
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
I. Input Quality (Students)								
1.	The increase in prospective students' interest	The percentage annual increase in prospective student enthusiasm.	**0%**	**0%**	**5%**	**10%**	**15%**	**20%**
2.	Adanya mahasiswa asing	The number of foreign full-time students per year.	**0**	**1**	**1**	**1**	**3**	**3**
		The number of foreign part-time students per year.	**27**	**30**	**33**	**35**	**38**	**40**
II. SDM DTPS Quality								
3.	Lecturer Position	The percentage of the number of teaching staff with the positions of Full Professor (GB) and Associate Professor (LK) to the total number of teaching staff (DTPS).	**54,54 %**	**57,5 %**	**60%**	**62,5 %**	**65%**	**70%**
4.	*Recognition of Teaching Staff (DTPS)*	The ratio of the number of recognitions of expertise to the total number of Teaching Staff (DTPS) each year.	**3**	**3**	**4**	**4**	**5**	**5**
5.	Relevant Teaching Staff (DTPS)	a. LN: The number of research with foreign funding sources in the last 3 years	**2**	**3**	**4**	**5**	**6**	**7**

No.	Objective	Indicator	2021 (*Baseline*)	2022	2023	2024	2025	2026
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	to the study program area	b. DN outside UGM: The number of research with domestic funding sources in the last 3 years	**25**	**26**	**27**	**30**	**32**	**35**
		c. DN inside UGM: The number of research with funding from the university/private sector in the last 3 years	**118**	**90**	**80**	**70**	**60**	**50**
6.	Community Service Activities (PkM) by Teaching Staff (DTPS) relevant to the study program's field.	a. LN: Number of Community Service Activities (PkM) with foreign funding sources in the last 3 years.	**7**	**3**	**4**	**5**	**6**	**7**
		b. DN outside UGM: Number of Community Service Activities (PkM) with domestic funding sources in the last 3 years.	**89**	**90**	**90**	**95**	**100**	**105**
		c. DN inside UGM: Number of Community Service Activities (PkM) with university/private funding sources in the last 3 years.	**42**	**42**	**43**	**43**	**44**	**45**
7.	Scientific publications with themes relevant to	a. Number of publications in international journals.	**36**	**36**	**37**	**38**	**39**	**40**
		b. Number of publications in reputable international journals.	**169**	**160**	**165**	**170**	**175**	**180**

No.	Objective	Indicator	2021 (*Baseline*)	2022	2023	2024	2025	2026
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	the field of study generated by teaching and research staff (DTPS).	c. Number of publications in international seminars.	**4**	**4**	**6**	**8**	**10**	**12**
8.	Scientific articles authored by teaching and research staff (DTPS) cited in the last 3 years.	Ratio of the Number of cited article titles (in the last 3 years) to the number of DTPS.	**5.7**	**5.7**	**5.8**	**5.8**	**5.9**	**6**
9.	Research and Community Service Outcomes (Non-Publication)	The ratio of the number of research/Community Service outcomes by lecturers (Non-Publications) recognized (Intellectual Property Rights, Copyright, Appropriate Technology, ISBN Books, Book Chapters) in the last 3 years compared to the number of teaching staff.	**2.3**	**2.4**	**2.5**	**2.6**	**2.7**	**2.8**
III. Quality of Study Program Recognition at UPPS								
1.	International Accreditation	Percentage of internationally accredited study programs	**40%**	**40%**	**40%**	**40%**	**60%**	**80%**

The strategies to achieve these goals are as follows:

1. Promoting through the distribution of leaflets, social media, other media channels, and direct promotions.
2. Enhancing networking and communication with partners and potential partners.
3. Facilitating and supporting the improvement of the quality and effectiveness of learning management.
4. Expanding services to the community in the fields of research, training, consulting, services, and more.
5. Launching activities involving international students.
6. Utilizing admissions through the GMIF and KNB pathways.
7. Introduction of programs to foreign universities.
8. Increasing collaboration with universities and research institutions abroad for research collaboration and program promotion.
9. Enhancing programs for mathematics schools in collaboration with international institutions.
10. Advancing the development of innovative research.
11. Providing and developing a well-integrated research roadmap.
12. Increasing the involvement of faculty members in research with domestic and international funding.
13. Conducting workshops on research proposal preparation techniques.
14. Enhancing faculty research to strengthen fundamental knowledge.
15. Increasing the presence of high-quality guest researchers to boost research innovation and collaboration possibilities.
16. Enhancing departmental grant funds and incentives for faculty research to stimulate collaborative research with external parties and research funded from outside UGM.
17. Increasing the number of publications.
18. Promoting multidisciplinary and transdisciplinary research with publication outputs.
19. Increasing faculty participation as speakers in academic forums.
20. Enhancing publication incentives and participation in academic forums as both presenters and resource persons.
21. Providing and developing an integrated PkM (Community Service) roadmap.
22. Conducting regular PkM activities every semester.
23. Strengthening collaboration with domestic and international institutions, including schools and universities.
24. Systematic development of PkM utilizing information technology, especially online learning, science, and discussion media.
25. Implementing a culture of quality through Internal Quality Audits (AMI) at the Department of Mathematics, UGM.

2.7 FACILITIES AND INFRASTRUCTURE

Teaching and learning activities within the Department of Mathematics, FMIPA UGM are supported by good physical facilities. The library facilities in the Department of Mathematics provide access to academic members who require various references in the fields of mathematics, statistics, and actuarial science, supporting both the learning and research processes. In addition to the department-level facilities, academic members also have access to the Faculty of Mathematics and Natural Sciences Library and the University Library, which have extensive collections of literature that can support the education and research processes. The University Library, in addition to providing physical services (in person), also offers virtual services in the form of e-resources, which include access to electronic books and journals subscribed to by UGM, as well as archives of thesis, dissertations, and dissertations. Access to these e-resources can be done on the website http://lib.ugm.ac.id.

In addition to reference libraries, the Department of Mathematics also has computer laboratories to support the learning process. These laboratories are equipped with computers with adequate specifications and licensed or open-source software. Currently, the Department of Mathematics is developing a computational laboratory for research purposes, which will be equipped with high-specification computers and software to support computational research development. Every academic member and educational staff member in the Department of Mathematics has an email account that is integrated with various technology-based services at UGM using the Single Sign-On (SSO) system. By using this account, all academic members in the Department of Mathematics can access various systems and services provided by the university, such as Simaster, the Learning Management System (Elok), e-resources at the UGM Library, and more.

In addition to the facilities mentioned above, academic members and educational staff also have access to various facilities provided by the university, such as healthcare facilities at GMC and the Academic Hospital, campus bike facilities, and more. In the learning process, in addition to face-to-face interactions, students can communicate with professors via email. Course assignments can be accessed online through the internet, and teaching materials are available in e-learning format through the Simaster portal (http://simaster.ugm.ac.id/) or Elok (https://elok.ugm.ac.id), which are freely accessible to students.

2.8 QUALITY ASSURANCE

The quality improvement and control system at the Department of Mathematics are carried out during the learning process as well as at the end of each semester in the internal quality audit process (AMI) conducted by the Quality Assurance Office (KJM UGM). The quality assurance process follows the Internal Quality

Assurance System at universities, consisting of 5 stages, namely Determination, Implementation, Evaluation, Control, and Improvement (PPEPP). This cycle is aimed at ensuring continuous improvement in the educational process in all study programs within the Department of Mathematics.

SPMI is carried out by the Quality Assurance Committee of the Department of Mathematics, which is the implementing team for quality assurance at the department level (UPPS). They are responsible for coordinating the development of curriculum structures to implement established quality standards and overseeing the implementation of the education process at the department level, including the improvement of human resources quality, the learning process, research, and community service.

CHAPTER 3 MASTER'S PROGRAMME IN MATHEMATICS

The Mathematics Masters Study Program was founded in 1992 with Government Decree Number 128/DIKTI/Kep./1992 dated 11 April 1992 with the aim of helping the government in developing education and research in the field of mathematics, both theory and application. The Master of Mathematics Study Program offers programs to students to enrich students with a good level of advanced mathematics skills, to prepare graduates to enter the world of work and for further studies. The implementation of educational and research programs in the Master of Mathematics Study Program at Gadjah Mada University is supported by 5 (five) Scientific Laboratories (research groups), namely

- **Analysis Laboratory / Research Group,**
- **Algebra Laboratory / Research Group,**
- **Applied Mathematics Laboratory / Research Group,**
- **Statistics Laboratory / Research Group, and**
- **Computational and Data Science Laboratory / Research Group,**

and offers 4 (four) areas of interest / concentration.

In the last 5 (five) academic years (AY 2017/2018 to AY 2021/2022), every year, the Master of Mathematics Study Program at Gadjah Mada University manages and educates approximately 125 to 200 students. For 30 years (from its founding in April 1992 to April 2022), the UGM Mathematics Masters Study Program has graduated approximately 1500 mathematics masters with various interests or concentrations. To ensure continuous improvement, the UGM Mathematics Masters Study Program is audited by the UGM Quality Assurance Office through Internal Quality Audit (AMI) activities every year, which are preceded by TKS (Semester Coordination Team) activities which are carried out at least twice in one semester. Furthermore, every 5 years it is accredited by the National Accreditation Board for Higher Education (BAN PT). Until the end of the 2021/2022 academic year, the UGM Mathematics Master's Study Program has always received an "Excellent" or "A" accreditation level.

As is believed by all parties, the quality of education certainly does not only depend on formal classes, but also depends on the academic atmosphere and good interaction between students, lecturers and other academic communities. To realize this condition, the UGM Mathematics Masters Study Program is trying its best to make it happen by holding

Colloquium, Workshop, Seminar, Conference and research and community service (PkM) activities involving students.

A Vision

The vision of the Mathematics Masters Program at the UGM Faculty of Mathematics and Natural Sciences is that **by 2037 it will become a Mathematics Masters Study Program that nationally excellent and is able to internationally competitive, both in theory and application, in order to realizing community welfare of society.**
The following is an explanation of each meaning of the Vision formulation above:

- **"Nationally Excellent"** means that the Master of Mathematics Study Program is always accredited by BAN / LAM with the Best rating ("Excellent" or "A"), the students are outstanding, the graduates can compete to be accepted for work in good jobs according to the graduate profile that has been determined ,
- **"Internationally competitive"** means that the graduates are able to compete with the Master of Mathematics Study Program in LN, the curriculum is equivalent to the curriculum of the Master of Mathematics Study Program in LN, the reference/reference books used in the transfer of knowledge are advanced standard reference/reference books from trusted publishing authors , the content (syllabus) complies with international regulations, and part of the research in his thesis resulted in publication in an international journal.
- **"Realizing community welfare"** means that lecturers' and students' research is oriented towards solving wider community problems, and lecturers' and students' PkM activities contribute to human development.

B Mision

The mission of the MP-Math, Faculty of Mathematics and Natural Sciences UGM are:

a. Organizing a qualified and innovative learning process to produce graduates who are adaptive and have the ability to develop themselves.
b. Improving the quality and quantity of research and publications, especially those involving students.
c. Improving the quality and quantity of services to the community, especially those involving students.
d. Improving the quality and number of outputs of lecturers, students, and graduates.
e. Improving the management system for the mathematics master study program that is transparent, accountable and fair.

C Program Educational Objective (PEO)

In general, the objective of the Mathematics Masters Study Program is to produce graduates at the mathematics master level who are able to make a positive contribution in realizing society's aspirations in the development of mathematics or the application of mathematics, both in the scientific community and in the general public, at international, regional and national levels. In addition, the Mathematics Masters Study Program aims to produce graduates who are adaptive in developing the potential, interests and strengths of mathematics, and have good attitudes and personalities, ready to develop or solve problems in other fields that require mathematics; as well as ready to continue their studies at a further level or to take part in various professions that require mature mastery and skills to apply mathematics.

In particular, the aim (Program Educational Objective/PEO) of the Mathematics Masters Study Program is to produce graduates at the master level of mathematics science who fear God Almighty and have integrity and have the competences to:

Table 3.1 : PEO-s of MP-Math

PEO-1	:	conduct research and development in the field of mathematics to produce innovative and tested works.
PEO-2	:	manage research and development that is beneficial to society and science, as well as receiving national and international recognition.
PEO-3	:	formulate an approach to solving various problems (problem solving approach) in people's lives in a scientific way through an inter/multi-disciplinary approach.
PEO-4	:	keep abreast of scientific developments continuously (become lifelong learners), especially in the field of mathematics and its applications

D Mapping of PEO and General Description of IQF Level 8

The curriculum of Mathematics Masters Study Program refers to the 2013 IQF level 8-based curriculum for higher education on masters programs as a form of equalizing the quality of human resources. In preparing the mapping between Study Program Objectives (PEO) and the IQF Generic Description, refer to the provisions of the "Guide to

Preparing Learning Outcomes (CP) for Study Program Graduates" which is in the following link:

- http://belmawa.ristekdikti.go.id/dev/wp-content/uploads/2015/11/6A-Panduan-Penyusunan-CP.pdf, and
- http://kkni-kemenristekdikti.org/pendidikan/deskripsi.

The following is a description of the General Formula of IQF Level 8.

IQF-1 Level 8	Capable to develop knowledge, technology, and/or art in their scientific field or professional practice through research, to produce innovative and tested works.
IQF-2 Level 8	Capable of solving problems of science, technology, and/or art in their field of science through an inter or multidisciplinary approach.
IQF-3 Level 8	Capable of managing research and development that is beneficial to society and science, and capable of getting national and international recognition.

This formulation is then used to create a mapping of the formulation of objectives (PEO) for the Master of Mathematics Study Program and a description of the General Formula of the KKNI. The mapping between Study Program Objectives (PEO) and the KKNI Generic Description is prepared based on the "Guide to Preparing Learning Outcomes (CP) for Study Program Graduates".

Table 3.2. Pemetaan PEO dengan IQF Level 8 (Magister)

	IQF-1	**IQF-2**	**IQF-3**
PEO-1	S	L	M
PEO-2	M	L	S
PEO-3	L	S	S
PEO-4	M	S	L

S: *strong* **M**: *medium* **L**: *light*

E Goals, Targets, Indicator of Achievements, and Strategy

The targets of Study Programs, Departments and Faculties within UGM are prepared to support the targets set by the university which have been formulated in the UGM Operational Plan (RENOP), which is the direction for measuring the achievement of the UGM Strategic

Plan (Renstra). Apart from that, the targets of the Master of Mathematics Study Program must also refer to the targets of FMIPA UGM as well as the targets of the Mathematics Department of FMIPA UGM as the management unit of the Master of Mathematics Study Program UGM. Target formulation is also determined based on selfevaluation of the study program and input from stakeholders. The targets to be achieved include achieving:

a. Input Quality
b. Process Quality and Academic Atmosphere
c. Tridharma Output Quality and Achievements
d. Quality of Dharma Research and PkM output involving students
e. Recognition Quality.

to be able to implement the Vision, Mission and Objectives of the Master of Mathematics Study Program, as can be seen on **Table 3.3** below.

Table 3.3. Goals, Indicators and Targets for the Next 5 Years

No.	Target	Indicator	2021 (*Baseline*)	2022	2023	2024	2025	2026
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
I. Input Quality (student)								
1.	Increased interest in prospective students	% Increased interest in prospective students per year	**0% (pandemic Covid 19)**	**5%**	**7.5%**	**10%**	**12.5%**	**15%**
2.	There are foreign students	Number of Full Time Foreign Students per year	**0**	**0**	**0**	**0**	**1**	**2**
	Input quality improvement strategy: • Carry out indirect promotions through distributing leaflets, social media, other media, and direct promotions. • Improve networking and communication with partners and potential partners. • Improving the quality of promotions through study program websites and social media. • Voucher scholarship programs and similar. • Increasing collaborative networks through PkM activities with regional universities involving alumni. • Socialization of study programs through activities such as open houses and open topics. Introduction of programs to foreign universities through research workshops, conferences, seminars, etc. • Launching activities involving overseas students. • Utilization of GMIF and KNB pathway acceptance forums. • Increased collaboration with universities and research institutions abroad in the context of research collaboration and study program outreach. • Improved joint mathematics school programs with international institutions.							
II. Process Quality and Academic Atmosphere								
3.	Integration of research and PkM activities in learning by DTPS in the last 3 years	Percentage of the number of courses developed based on the results of DTPS research/PKM in the last 3 years compared to the total number of all courses	**15.3%**	**20%**	**30%**	**35%**	**40%**	**50%**

No.	Target	Indicator	2021 (*Baseline*)	2022	2023	2024	2025	2026
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
4.	Number of DTPS research titles whose implementation involved students	Percentage of the number of DTPS research titles whose implementation involved study program students in the last 3 years compared to the number of DTPS research titles in the last 3 years	**10%**	**15%**	**25%**	**35%**	**40%**	**50%**

	Strategy to improve the quality of academic processes and atmosphere: • Implement problem based learning and case based study. • Increasing PkM with research materials which are learning materials. • Provide incentives for writing learning materials which are the integration of research/PKM results of Study Program lecturers. • Continuously integrate the latest research results into the learning system. • Increased presence of qualified visiting researchers to increase research innovation and collaboration possibilities.							
III. Tridharma Output Quality and Achievements								
5.	GPA	Average GPA of graduates in the last 3 years	**3.47**	**3.47**	**3.47**	**3.48**	**3.49**	**3.50**
6.	Student achievements in the academic field in the last 3 years	Percentage of student academic achievements at national and international levels compared to the number of active students	**23%**	**23%**	**25%**	**25%**	**27,5%**	**30%**
7.	Length of Study	Average graduate study period (years) TS-3 to TS-1	**2.58 th**	**2.75 th**	**2.7 th**	**2.65 th**	**2.6 th**	**2.5 th**
8.	Success in the Graduate Search Study	Percentage of TS-4 to TS-2 graduates who were traced (the number traced compared to the number of TS-4 to TS-2 graduates)	**35%**	**40%**	**45%**	**50%**	**55%**	**60%**
	Strategy to improve the quality of outcomes and achievements of the Tridharma: • improve the process and quality of monitoring the implementation of thesis I and thesis II guidance. • provide assistance to students' difficulties in overcoming obstacles in mastering several mandatory MK by providing tutorials. • Sharing alumni about publication tips and completing python, R, Matlab, and LaTex software programs and training. • Publication incentive program and participation in scientific seminars. • Good assessment standardization and continuous evaluation process. • Establishment of an alumni community. • Improve networking and communication with partners and potential partners.							
IV. Quality of Dharma Research and PkM output involving students								
9.	Scientific publications student, that is	a. Number of publications in international journals	**1**	**2**	**3**	**4**	**5**	**6**

	generated automatically independently or together DTPS, with title relevant to field of study program in the last 3 years	b. Number of publications in reputable international journals	**2**	**3**	**4**	**5**	**6**	**7**
		c. Number of publications at international seminars	**14**	**10**	**11**	**12**	**13**	**14**
10.	Student scientific work articles, which generated automatically independently or together with DTPS, which is cited in the last 3 years	Number of student article titles cited in the last 3 years	**3**	**4**	**5**	**6**	**7**	**8**
11.	Research output and PkM (non-publication) produced by students, either independently or with DTPS in the last 3 years	Number of research outputs/PKM produced by students that received recognition (IPR, or, Copyright, Appropriate Technology, Books with ISBN, Book Chapters) in the last 3 years	**0**	**1**	**1**	**1**	**1**	**2**
	Strategies for increasing research and PkM dharma outputs involving students: • Increase department/faculty grants for lecturer research involving students. • Workshop on writing publications and tips on publication and journal selection. • Incentives for publication of seminars and workshops or similar. • Organizing international level scientific forums by inviting foreign speakers. • Utilization of Final Project Recognition grants provided by UGM Increased research grants by DIKTI or LPDP or other institutions. • Increasing the participation of lecturers as speakers in international scientific forums as part of research dissemination with students. • Improve the quality and effectiveness of learning management. • Improve services to the community in the fields of research, training, consultation, services, etc.							
V. Recognition Quality of Study Program								

12.	International Accreditation	Accreditation Process		Preparation for mapping the Curriculum	Preparation of documents	Submission of accreditatio n documents	Preparation for visitation	Obtained accreditation
	Strategy to improve the quality of PS recognition: • Implement the principles of outcome-based education. • Implementing a quality assurance process for continuous improvement through AMI and TKS activities, and preparing a portfolio to measure CO-PLO achievements. • Collaborate with domestic and foreign universities to improve the quality of study programs.							

F References ini Preparing the Curriculum

The 2022 Curriculum for the Master of Mathematics Study Program was prepared by taking into account the analysis of internal self-evaluations in activities so called **SWOT (Strength, Weakness, Opportunity, and Threat) Analysis untuk meningkatkan RAISE (Relevance, Academic atmosphere, Internal management and organization, Sustainability, Efficiency and productivity)**. Apart from internal evaluation activities, implementation of the 2017 Curriculum is carried out through activities AMI, TKS activity, as well as the results of **tracer study**. The 2022 Curriculum for the Master of Mathematics Study Program is prepared in accordance with the objectives of the study program based on laws, regulations and other provisions as follows:

1. Legal Law No. 20, published in 2003 about the National Education System (SISDIKNAS)
2. Legal Law No. 12, published in 2012 about Higher Education (DIKTI).
3. Government regulation No. 4/2014 About the management of higher education.
4. President regulation No. 8/2012 about the Implementation of the Indonesian National. Qualification Framework IQF (KKNI) junto Number 44 the Year 2015.
5. Government regulation No. 57/2021 about the National Education Standard of Indonesia.
6. Regulation of the Minister of Education and Culture No.73/2013 About IQF (DIKTI) implementation. Regulation of the Minister of Education and Culture No.50/2014 About University Quality Assurance System (JAMU DIKTI).
7. Regulation of the Minister of Education and Culture No.81/2014 About Diploma certification, Supplement Diploma, and DIKTI Professional certificate. Regulation of the Minister of Education and Culture No.87/2014 About Study Program Accreditation and University.
8. Regulation of the Minister of Education and Culture Nomor 3/2020 About National Standard of University. Rector Regulation No.16/2016 About the Fundamental Framework of Curriculum in UGM and No. 14/2020 about the Fundamental Framework for the Curriculum of the Universitas Gadjah Mada.
9. Rector Regulation No.11/2016 about Postgraduate Education and No.18/2019 about Implementation of the Research-Based Postgraduate Program at Universitas Gadjah Mada
10. Foresighting sciences study document in Faculty of Mathematics and Natural Science, Senate FMIPA UGM 2016.
11. Curriculum Guidebook, Dirjen Dikti, Kemenristekdikti 2019. Curriculum document of master’s Program of FMIPA UGM in 2017. Addendum to the curriculum document for the FMIPA UGM Master Program in 2021 Based on Research. Scientific Mandate of FMIPA UGM. MBKM Guidebook, Ditjen Dikti, Kemendikbud, 2020.

12. Input from Alumni and Stakeholders from tracer study (graduate users, society, industry, and others) in 2020 and 2021.
13. Internal Evaluation of 2017 Curriculum for MP-Math.
14. Results of the Internal Quality Audit (abbreviated as AMI in Bahasa) during the period 2017 – 2021.
15. The results of the evaluation of the Semester Coordination Team (TKS) for the period 2017 - 2021.
16. Revised Bloom's Taxonomy (https://en.wikipedia.org/wiki/Bloom%27s_taxonomy#/media/File:Bloom's_Revised_Taxonomy.jpg)

Apart from that, in compiling the 2022 Curriculum, the Master of Mathematics Study Program also took into account various recommendations from professional organizations related to mathematics at the international level, such as the recommendations in the following documents:

1. The Document of 2015 CUPM Curriculum Guide to Majors in the Mathematical Sciences yang diterbitkan oleh MAA [22]. https://www.maa.org/sites/default/files/CUPM%20Guide.pdf
2. The Document of CUPM Discussion Papers about Mathematics and the Mathematical Sciences in 2010: What Should Students Know? dipublikasikan oleh Mathematical Association of America [23]. http://www.maa.org/sites/default/files/pdf/CUPM/math-2010.pdf
3. The Document of Society for Industrial and Applied Mathematics (SIAM) SIAM Guidelines for a Professional Master's Degree [24]. https://archive.siam.org/students/resources/guidelines.php
4. The Document of The SIAM Report on Mathematics in Industry 2012 dipublikasikan oleh SIAM [25]. http://www.siam.org/reports/mii/2012/report.php
5. The Document of lembaga akreditasi internasional: ASIIN Subject-Specific Criteria of the Technical Committee 12 – Mathematics [26]. https://www.asiin.de/files/content/kriterien/ASIIN_SSC_12_Mathematics_2016-12-09.pdf
6. The Document of Curriculum Guidelines for Undergraduate Programs in Statistical Science (American Statistical Association, 2014) [27]. https://www.amstat.org/education/curriculum-guidelines-for-undergraduate-programs-in-statistical-science-
7. The Document of Report of the ASA Workgroup on Master's Degrees [28]. https://www.amstat.org/docs/default-source/amstat-documents/masterworkgroup.pdf
8. The Document of Statistics Education Graduate Programs Report On A Workshop Funded by An ASA member initiative grant [29]. https://www.amstat.org/docs/default-source/amstat-documents/edu-statedgraduateprograms.pdf

9. The Document of 2017 Updated IAA Education Syllabus dari International Actuarial Association (IAA) [30]. https://www.actuaries.org/CTTEES_EDUC/Documents/2017_IAA_Education_Syllabus.pdf

Apart from that, in preparing the 2022 Curriculum, we also pay attention to the results of online benchmarking, especially the formulation of Compulsory MK (core), specializations (Major / Minor) and the formulation of graduate learning outcomes. Online Benchmarking activities for several Graduate Program in Mathematics curricula from various universities with mathematics programs in foreign countries from various parts of the world, including:

1. Japan
   a. Kyushu University
      https://www.math.kyushu-u.ac.jp/eng/
   b. Nagoya University
      http://www.math.nagoya-u.ac.jp/
   c. Waseda University
      https://www.fse.sci.waseda.ac.jp/dept-en/math/
2. ASEAN Countries
   a. NUS
      https://www.math.nus.edu.sg/
   b. NTU (Singapore)
      https://www.ntu.edu.sg/spms/about-us/mathematics
   c. Ateneo University (Filipina)
      https://www.ateneo.edu/ls/sose/mathematics/ateneo-mathematics-art-culture-and-creativity-laboratory
   d. Mahidol University (Thailand)
      https://mathematics.sc.mahidol.ac.th/
3. Europe
   a. University of Groningen (The Netherlands)
      https://www.rug.nl/masters/mathematics/?lang=en
   b. University of Oslo (Norwegia)
   https://www.mn.uio.no/math/english/
4. AUSTRALIA
   a. Australian National University (ANU)
      https://maths.anu.edu.au/
   b. University of New South Wales
      https://www.maths.unsw.edu.au/
5. USA
   a. Stanford University
      https://mathematics.stanford.edu/
   b. Harvard University
      https://www.math.harvard.edu/

G Proffesion / Graduate Employment

Based on tracer studies conducted online in 2021 and 2022, it was found that the majority of graduates work in the academic field (80%) as lecturers and teachers spread across all provinces in Indonesia. Some other graduates work as consultants, private company employees and practitioners; for example as a civil servant in a ministry, in an insurance company as an actuary, the Financial Services Authority and financial institutions. These graduates, especially those who work as teachers and lecturers, work in various places in Indonesia.

Graduates of the Master of Mathematics Study Program are expected to be able and have core competences in advanced mathematical theory, namely advanced linear algebra, analysis, mathematical statistics, and mathematical and computational modeling and can apply them in one or several fields of application and further theory.

Graduates are expected to be able to construct mathematical models to solve real problems, as well as be able to conduct studies on accuracy and be able to deepen or expand mathematical knowledge by producing accurate, tested and innovative models/methods/theoretical developments. The Mathematics Master's Study Program as a program between the Mathematics Bachelor's Program and the Mathematics Doctoral Study Program, aims to finalize things that have been started at undergraduate level as preparation for fields of work that require a higher use and understanding of mathematics.

H Graduate Profile

Graduates of the Mathematics Masters Study Program are expected to be able and have core competences in advanced mathematical theory namely advanced linear algebra, analysis, mathematical statistics, and Mathematical modeling and computation can apply them in one or several fields of application and further theory. Graduates are expected to be able to construct mathematical models to solve real problems, and be able to conduct studies on accuracy and be able to deepen or expand mathematical knowledge by producing models / methods / theory development that are accurate, tested, and innovative.

The Mathematics Masters Study Program as a program between the Mathematics Undergraduate Study Program and the Mathematics Doctoral Study Program, aims to finalize things that have been started at the undergraduate level as preparation for fields of work that require a higher use and understanding of mathematics. In general, the Profile of Graduates of the Mathematics Masters Study Program is expected to work as:

- **Academics,**
- **Associate Researchers,**
- **Consultants, or**
- **Practitioners**

Academics

- In general, an academic is someone who works in a field of expertise, but is more oriented towards the world of education, such as a lecturer and teacher.
- In the context of the graduate profile of the Master of Mathematics Study Program, what is meant by an academic is a person who carries out teaching and research activities in an institution or educational environment related to the fields of mathematics, statistics, actuarial, or fields related to mathematics.

Associate Researchers

- In general, a researcher is a person who plays a role in a research group by carrying out activities using a certain system to obtain knowledge or carrying out a number of practices which can traditionally be associated with thinking or philosophical activities.
- In the context of the graduate profile of the Master of Mathematics Study Program, what is meant by researcher is a person who carries out research activities at an institution in the fields of mathematics, statistics, actuarial, or fields related to mathematics.

Consultants

- In general, a consultant is an expert whose job is to provide guidance, consideration or advice in an activity (research, trade, etc.); advisor. Consultants are also professionals who provide advisory services in certain fields. Apart from that, a consultant is someone whose main task is to provide consideration of policies or suggest a policy in an activity or organization. Consultants are also often referred to as expert staff, who are often used as a place to ask questions.
- In the context of the graduate profile of the Master of Mathematics Study Program, what is meant by consultant is an expert whose job is to provide guidance, consideration or advice in an activity (research, trade, etc.); advisor in mathematics, statistics, actuarial, or fields related to mathematics.

Practitioners (INDUSTRY, SERVICES, GOVERNMENT):

- In general, a practitioner is someone who is experienced in their field or someone who specializes in something. Usually a practitioner is someone who operates in the industrial sector. The practitioner profession is an implementer of a business; an implementer of a company's business activities.
- In the context of the graduate profile of the Master of Mathematics Study Program, a practitioner is an experienced person in their field

or someone who is in a field who is qualified to do (practice) a job or profession in the field of mathematics, statistics, actuarial, or a field related to mathematics

This profile is supported by competencies formulated as in the Learning Outcomes section described in the following section.

I Program Learning Outcomes (PLO)

Referring to the profile of graduates formulated above, the learning outcomes **(Program Learning Outcomes/PLO)** of the Mathematics Masters Study Program are formulated as follows:

Table 3.4. The PLO-s of MP-Math

PLO-1	:	**Attitudes and Values:** Have the following attitudes and values: Fear of God Almighty, uphold human values, internalize academic values, norms and ethics, be responsible for work in the field of expertise independently.
PLO-2	:	**General Knowledge (Core competences):** Mastering the main concepts of mathematics (Analysis, Advanced Linear Algebra, Mathematical Statistics, Modeling and Computing) methodology, and its interrelation.
PLO-3	:	**Specific Knowledge:** Having mastery of comprehensive knowledge in one or several theories for development a. analysis field b. algebra and combinatorics c. fields of applied mathematics and computing d. statistics and data science
PLO-4	:	**General Skills:** Able to identify scientific fields that are the object of his research and position them into a research map that is developed creatively, innovatively, and tested through a multidisciplinary or interdisciplinary approach and communicates it to the academic community.
PLO-5	:	**Special Skills:** Mastering knowledge of current issues, developments in the field of mathematics, especially those related to theory and its applications, through a learning process that is of national and international standards.
PLO-6	:	**Life Long Learning:** Understand and be able to live the philosophy of lifelong learning and be adaptive to the development of science and technology, especially fields related to mathematical theory and its application and have an instinct in developing or applying mathematics and developing new challenges.

Referring to The subject-specific criteria (SSC) of the Technical Committee 12 Mathematics

https://www.asiin.de/files/content/kriterien/ASIIN_SSC_12_Mathematics_2016-12-09.pdf
we formulate the following **table showing** Relationship between the 12th SSC ASIIN Standard with PLO for MP-Math. The MP-Math is designed as 2 years program with type M which is a Degree program in Mathematics with a minor or an applied subject.

Table 3.5. The Mapping Between
The subject-specific criteria (SSC) and PLO-s of MP-Math

No	Subject Specific -12 Type M	PLO -1	PLO -2	PLO -3	PLO -4	PLO -5	PLO -6
1	**Knowledge**						
	• **Remember:** possesses further knowledge of abstract and applied mathematics as well as at least one minor		V	V	V		
	• **Comprehend:** ▪ is able to identify and explain the quality of complex mathematical problems ▪ is able to generalize complex mathematical problems		V	V	V		
2	**Ability**						
	• **Apply:** ▪ is able to use mathematical statements to solve mathematical problems ▪ is able to formulate mathematical hypotheses and verify them				V	V	V
	• **Analyze:** ▪ recognizes the mathematically abstract structure of problems and is able to analyze this			V	V	V	
3	**Competence:**						
	• **Evaluate:** ▪ Formally and correctly proves	V			V	V	

	mathematical statements ▪ Masters' strategies to transfer methods within a wide area of Mathematics						
	• **Create:** ▪ Implements mathematical processes for complex problems on the computer by applying mathematical standard software ▪ Is able to scientifically work on and present mathematical problems • Within the area of abstract and applied mathematics or a minor with a close mathematical relation • Within the framework of Master activities, independently works on an advanced scientific o within the area of abstract and applied mathematics or a minor with a large mathematical proportion o and is able to adequately present and scientifically discuss the results both orally and in writing	V				V	V

The mapping of PEOs and PLOs could be seen in **Table 3.6** as follows.

Table 3.6. Mapping of PEOs and PLOs

PEO	Program Learning Outcome (PLO)					
	PLO 1	PLO 2	PLO 3	PLO 4	PLO 5	PLO 6
PEO 1	M	M	H	H	H	H
PEO 2	M	M	H	M	H	H
PEO 3	L	M	H	H	H	H
PEO 4	M	H	M	M	H	M

H : High **M : Medium** **L : Low**

The intended learning outcomes of the MP-Math (PLO) meets the 8th level of IQF (Indonesia Quality Framework). The relationship between the 8th level of IQF and PLOs of MP-Math is shown in **Table 3.7**.

Table 3.7. The relationship between the 8th level of IQF and PLOs of MP-Math.

IQF	Programme Learning Outcome (PLO)						
	PLO 1	**PLO 2**	**PLO 3**	**PLO 4**	**PLO 5**	**PLO 6**	**PLO 7**
IQF 8.1	M	M	H	H	H	H	L
IQF 8.2	M	M	H	H	H	H	L
IQF 8.3	M	M	H	H	H	H	H

H : High **M : Medium** **L : Low**

J Learning Experiences and area of interests.

With reference to the formulation of graduate profiles; and the Learning Outcome (Program Learning Outcome - PLO) that has been formulated above; as well as taking into account recommendations and benchmarks with several similar study programs at several tertiary institutions in country and abroad, the areas of study (learning experiences) for the Mathematics Masters Study Program are compromises from the following 4 areas:

a. area of interest in **analysis**
b. area of interest in **algebra and combinatorics**

c. area of interest in **applied mathematics and computation**
d. area of interest in **statistics and data science.**

The curriculum for the Mathematics Masters Study Program consists of a set of course units and a thesis. Courses are arranged based on the competencies expected of graduates of the Mathematics Masters Study Program, which are divided into

- study program compulsory courses,
- interest compulsory courses and
- elective courses.

The thesis is required to fulfill intellectual development competencies and is done in two parts, first part is Thesis I (2 credits) and second part is Thesis II (6 credits). Thesis I aims to assess student competence in determining research topics and materials, methodology and research plan feasibility. Thesis II aims to assess student competence in conducting research, mastery of material and writing scientific papers.

a. Area of interest in analysis

Analysis (derived from the ancient Greek ἀνάλυσις which means a breaking-up, an untying (solving, releasing, separating); from the words: ana (throughout) and lysis (a loosening) is the process of breaking down complex problems or substances into smaller parts to get a better understanding.

Mathematical Analysis, abbreviated as analysis, is a branch of mathematics that studies problems related to continuous change, the approach of a mathematical object (such as numbers and functions) by another object, for example the number π is studied using number sequences, functions are studied using limit (infinitesimal method). Analysis also studies problems related to space formed by collections of objects equipped with the concepts of nearness and distance (metrics). Analysis can be viewed as an evolution of calculus, which includes basic concepts and analytical techniques. Analysis is also developing, one of which is by generalizing and abstracting concepts and properties in the real number system such as distance, length and sequence. Analysis teaches and trains analytical and systematic thinking, so that it can help in solving new, non-standard/standard problems. Thus, Mathematical Analysis is an important foundation for the development of concepts and methods, both in mathematical analysis itself, branches of mathematics outside analysis, and its applications.

Analysis includes, among others, real analysis (such as real number systems, sequences, limits, derivatives, real functions) and their generalizations/abstractions (for example metric spaces), complex analysis, differential and integral equations, measure and integral theory, functional analysis (including operator theory, function spaces, sequence spaces, Riesz spaces), topology, and fixed point theory.

b.Area of interest in algebra and combinatorics

Algebra is a branch of mathematics that studies mathematical symbols or symbols along with the rules for manipulating these symbols. The scope of algebra studies ranges from simple things such as finding solutions to equations to abstractions that give rise to groups, rings and fields. The simple algebra section is usually used in other fields of science such as economics, engineering or applied mathematics. Meanwhile, abstract algebra is an object of research for mathematicians, which does not rule out the possibility of several applications in other fields.

Apart from being the name of a branch of mathematics, algebra is also the name of a mathematical system or structure. In its development, there are special algebras which have become objects of research in the field of algebra, for example linear algebra, Lie algebra, non-associative algebra, commutative algebra, topological algebra and so on. Furthermore, the approach through algebra is also often added to the names of certain objects such as algebraic geometry and algebraic topology.

The development of algebra research was largely motivated by observations of the properties of numbers or was generally inspired by properties in number theory which made the field of algebra quite close to that theory. On the other hand, number theory research involves a lot of observation or combinatorial calculations, so that graphs and combinatorics can also be linked to algebra.
The Algebra Laboratory has a mandate to emphasize the steps that need to be taken in order to achieve its goal, namely to become a reference for theoretical algebra research in the fields of rings, modules, number theory and graphs, as well as collaborating with other fields to develop applied algebra.

Based on this idea, the areas of interest being developed need to be stated explicitly, namely algebraic structures and combinatorics. Included in the study of algebraic structures are ring theory, module theory, as well as development structures such as semigroups, semirings, coalgebras and comodules. Meanwhile, the field of combinatorics includes graph theory, number theory, cryptography and related fields. Topics around linear systems and coding theory are areas of algebra application which are areas of study and directions towards application. In various mathematical modeling techniques, knowledge of matrices and all their characteristics is very necessary. Therefore, knowledge of matrix analysis is also a mandatory study for those interested in the field of algebra. The

Kapita Selekta course is a place to study the latest developments in algebra with topics that are adjusted at any time.
Apart from carrying out the mission of developing and applying the field of algebra, as part of the field of mathematics in general, it needs a strong foundation in mathematical philosophical thinking through, among other things, category theory, fuzzy logic and latical theory.

c.Area of interest in applied mathematics and computation

Applied Mathematics connects concepts (Algebra, Analysis, Statistics) and mathematical techniques with various other fields of science or their application to real problems.
The aim of Applied Mathematics research is not only to intelligently apply existing mathematical tools and insights to solve problems, but also to develop new theories or methods that can be inspired and driven by real applications/problems. Computing technology is very necessary, both new methods and the application of existing methods to new problems. Computational technology is important for validating new or developed methods by examining the accuracy of estimates and interpretation of results, both qualitatively and quantitatively. Therefore, it is necessary to form an Interest in Applied Mathematics and Computing. This area of interest has three types of studies, namely theoretical studies, numerical studies and thematic studies. Theoretical studies cover four major areas, namely:

c.1. Field 1:
Differential Equations, Dynamical and Bifurcation Systems, and Perturbation Theory,

c.2. Field 2:
Control Theory and Systems Theory,

c.3. Field 3:
Optimization Theory, Game Theory, Operations Research, Fuzzy Programming, Random Fuzzy Programming, and Stochastic Optimization, Queuing Theory, and

c.4. Field 4:
Mathematical models are either deterministic, probabilistic, or stochastic models.

Numerical studies are based on computational theory and the development of computational methods as well as the application of mathematical computing techniques, including Optimization, Ordinary and Partial Differential Equations, Inverse Problems, Machine learning, Deep learning and Big Data.

Fields of study that are thematic and based on real problems in society, include Modeling the Spread of Cancer and its Treatment, Modeling Healthcare and Hospital Management, Climate Modeling related to Food

Security, Tropical Diseases, and Agricultural Insurance, Biometric Modeling, Applications in Economics, Healthcare and Traffic Management.

These areas of study are integrated into compulsory courses of interest, elective courses, and theses. Apart from theoretical or numerical theses, in the future it is possible to develop new thematic theses as a response to various problems occurring in society.

d.Area of interest in statistics and data science.

In general, Statistics and Data Science interests relate to modeling and analyzing data, designing experiments, making inferences, predictions, and decisions in the face of uncertainty. The main interest of this field is the application of Statistics; applied problems that trigger the development of new methods and new applications of advanced statistical methodologies. This statistics lies in various fields of statistics, ranging from theoretical studies to applied studies. Not only that, this interest in Statistics is also interested in developing new Statistical methodologies for complex data, especially those emerging such as in the fields of Biology, Financial Statistics, Actuarial and Computational Statistics and Data Science.

d.1.Field of Statistics

This field focuses on the application of probability theory, which is a branch of mathematics. Specific mathematical techniques used for this include mathematical analysis, linear algebra, stochastic analysis, differential equations, and measurement theory. Field of work: Lecturer, researcher.

d.2. Actuarial Field

This field of science uses probability theory, mathematics, statistics and economics to measure and calculate the financial impact of uncertain events in the future. Several courses in this field can be used to obtain equivalent PAI (Indonesian Actuary Association) actuarial professional certification. Students interested in Actuarial can also do practical work (non-SKS) according to offers from insurance companies that collaborate with the Study Program. Meanwhile, the Actuary profession can work in the fields of: Life Insurance, General Insurance, Healthcare, Pension, Employee Benefits, Social Policy and Finance, Investment and Risk Management.

d.3.. Field of Financial Statistics

Financial statistics encompasses the field of science that analyzes all numerical data that summarizes the past behavior or forecasts the future behavior of an individual financial security, a group of securities, or a market over a large geographic area. Market or industry statistics track the activity of a specific set of securities linked by a common trading market or industry classification. Company-specific statistics examine the performance of individual companies. Field of work: Securities-stock market, financial industry, Insurance, investment companies.

d.4. Field of Statistical Computing and Data Science

Statistical Computing is the interface between statistics and computer science. This means that statistical methods are activated using computational methods. This is a field of computational science (or scientific computing) specific to the mathematical science of statistics. This area is also growing rapidly, leading to calls that broader computing concepts should be taught as part of general statistics education.

As in traditional statistics, the goal is to transform raw data into knowledge, but the focus is on computer-intensive statistical methods, as is the case with very large sample sizes and inhomogeneous data sets. The terms 'computational statistics' and 'statistical computing' are often used interchangeably, although there are also proposals to distinguish between these two terms, 'statistical computing' is defined as "the application of computer science to statistics", and 'computational statistics' as "aimed at the design of algorithms for apply statistical methods on computers, including those that were unthinkable before the computer era (e.g. bootstrapping, simulation), as well as to solve problems that are difficult to solve analytically". The term 'computational statistics' can also be used to refer to computationally intensive statistical methods including resampling methods, Markov chain Monte Carlo methods, local regression, kernel density estimation, artificial neural networks and generalized additive models.

Data science is a scientific discipline that specifically studies data, especially quantitative data (numerical data), both structured and unstructured. The various subjects discussed in data science include all data processes, starting from data collection, data analysis, data processing, data management, archiving, data grouping, data presentation, data distribution, to how to transform data into a unified piece of information that everyone can understand.
Data science is a combination of science and social science. The main supporting sciences in data science consist of mathematics, statistics, computer science, information systems, management, information science, including communication science and library science, archives and documentation. Even economics, especially business science, also plays an important role in science data.

K The Structure of The 2022 Curriculum

There are two kinds of program tracks in the MP-Math that can be taken by students in order to achieve a Master degree in Mathematics with the qualification explained in the PLO of the MP-Math. Those two program tracks are:

1. **Regular track, and**
2. **By Research track.**

Students of both tracks have to complete a minimum of 44 credits to complete their study.

K.1. Regular Track

The 44 credits course is supposed to be finished by the student in two years, although it can also be finished in one year. The minimum 44 credits consist of

- **12 credits of compulsory courses for all students,**
- **9 credits of compulsory courses for the chosen interest,**
- **minimum 15 credits maximum 21 credits of free elective courses, and**
- **8 credits of final project (thesis).**

All students of both tracks are required to take the compulsory courses. The elective courses for the regular track are divided into four fields of interest according to the four expert groups in the Mathematics Department UGM. The elective courses of the By Research track are designed to help students of this track to conduct and complete their research. The following table showing the structure of the curriculums:

The Master of Mathematics Study Program curriculum consists of course units and a thesis. Courses are arranged based on the competencies expected of graduates of the Master of Mathematics Study Program, as listed in Table 2.4, which are divided into compulsory study program courses, compulsory interest courses and elective courses.

The thesis is required to fulfill intellectual development competencies and is done in two parts, Thesis I (2 credits) and Thesis II (6 credits). Thesis I aims to assess student competence in determining research topics and materials, methodology and feasibility of research plans. Thesis II aims to assess student competence in conducting research, mastering material and writing scientific papers.

In **Table 3.8** below, the structure of the Master of Mathematics Study Program Curriculum structure is presented based on the distribution of study load components and study interests. The choice of interest will be determined no later than the beginning of Semester II. Meanwhile, the recommended intake scheme for each semester for each interest can be seen in Table 2.5. For thesis work, in general the decision can be made based on 2 (two) alternatives.

- **Alternative A**

Thesis I and Thesis II can be taken separately in different semesters, namely in Semester III and Semester IV.

- **Alternative B**

Thesis I and Thesis II were taken simultaneously in semester IV, and all elective courses were completed in semester III.

Table 3.8.The Structure of The Curriculum

Description	CU	Courses
Compulsory Courses **for all students**	12 CU	**For all students (as core competences courses)** 1. Analysis I (3 CU) 2. Advanced Linear Algebra (3 CU) 3. Mathematical Statistics I (3 CU) 4. Mathematical Modelling and Computation (3 CU)
Compulsory Courses **for the Chosen Interest**	9 CU	**For students interested in analysis track (9 CU):** 1. Analysis II (3 CU) 2. Functional Analysis (3 CU) 3. Topology (3 CU)
		For students interested in in algebra and combinatorics track (9 CU): 1. Algebraic Structures (3 CU) 2. Graph Theory and Combinatorics (3 CU) 3. Matrix Analysis (3 CU)
		For students interested in in applied mathematics and computation track (9 CU): 1. Optimization Theory (3 CU) 2. Deferential Equations (3 CU) 3. Applies Computational Analysis (3 CU)
		For students interested in statistics and data science track. (9 CU): Students have to choose 3 courses between 5 following courses: 1. Stochastic Process (3 CU) 2. Multivariate Analysis (3 CU) 3. Financial Mathematics (3 CU) 4. Machine Learning (3 CU) 5. Applied Statistical Computing I (3 CU)

Free Elective Courses	Min. 15 CU Max. 21 CU	In addition to taking 12 CU Compulsory Study Program, 9 CU Compulsory Courses for the Chosen Interest, and 8 CU Thesis, students must take a minimum of 15 CU of elective courses and a maximum of 21 CU, provided that a minimum of 12 CU are Elective Subjects from within their field of interest, (grouping courses in a field of interest listed in the following table)
Thesis (Final Project)	8 CU	1. Thesis I (2 CU) 2. Thesis II (6 CU)

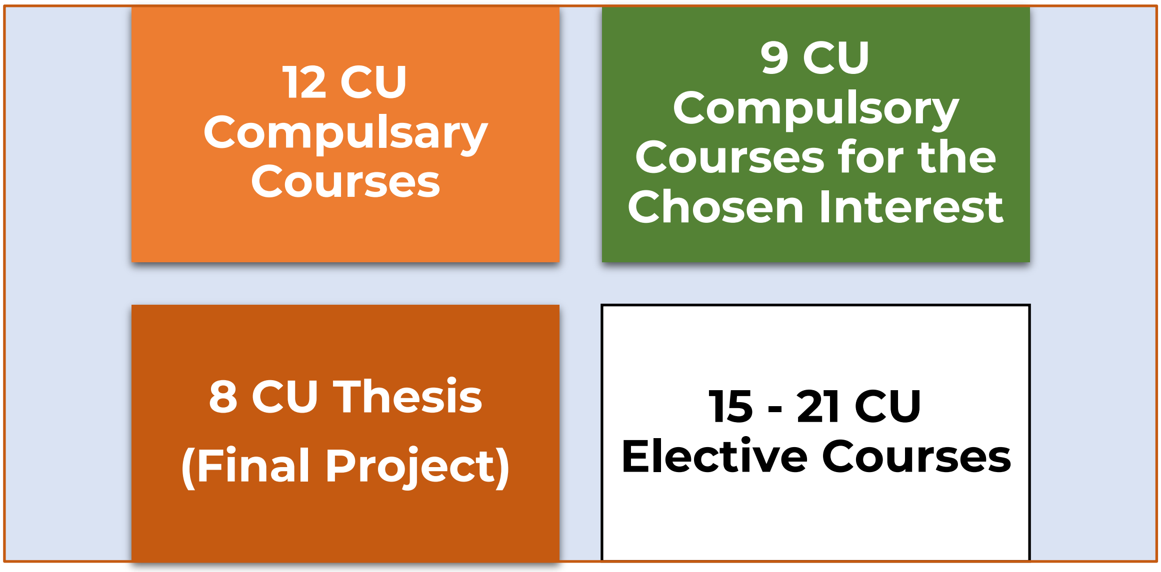

Diagram 3.9. The Diagram of The Structure of The Curriculum

The following table showing the design plans of student's workload in each semester:

Table 3.10
Study Plan Per Semester (in 4 Semesters) Per Student Track / Interest Choice

	Analysis Track / Interest	**Algebra and Combinatorics Track / Interest**	**Applied Mathematics and Computation Track / Interest**	**Statistics and Sciences Data Track / Interest**
Semester I (15 CU)	**9 CU compulsory Courses for all students :** • Analysis I (3 CU) • Advanced Linear Algebra (3 CU) • Mathematical Statistics I (3 CU)			
	3 CU compulsory Courses for	6 CU Electives Courses	6 CU Electives Courses	6 CU Electives Courses

	Analysis Track: Topology (3 CU)			
Semester II (maximum 15 CU)	**3 CU compulsory courses for all students**: Mathematical Modelling and Computation	**3 CU compulsory courses for all students**: Mathematical Modelling and Computation	**3 CU compulsory courses for all students:** Mathematical Modelling and Computation	**CU compulsory courses for all students**: Mathematical Modelling and Computation
	6 CU compulsory Courses for Analysis Track/Interest: Analysis II (3 CU) Functional Analysis (3 CU)	**9 CU compulsory Courses for Algebra and Combinatorics Track/Interest:** 1. Algebraic Structures (3 CU) 2. Graph Theory and Combinatorics (3 CU) **3.** Matrix Analysis (3 CU)	**9 CU compulsory Courses for Applied Mathematics and Computation Track/Interest:** 1. Optimization Theory (3 CU) 2. Deferential Equations (3 CU) **3.** Applies Computational Analysis (3 CU)	**9 CU compulsory Courses for Statistics and Sciences Data Track/Interest** choosing 3 courses from 5 following courses: 1. Stochastic Process (3 CU) 2. Multivariate Analysis (3 CU) 3. Financial Mathematics (3 CU) 4. Machine Learning (3 CU) **5.** Applied Statistical Computing I (3 CU)
	Elective Courses (maximum 6 CU)	Elective Courses (maximum 3 CU)	Elective Courses (maximum 3 CU)	Elective Courses (maximum 3 CU)
Semester III	***Alternative A:*** Thesis I (2 CU) and Elective Courses (6 – 12 CU)			
	Alternative B: Elective Courses (9 – 15 CU)			

8 till 14 CU	
Semester IV 6 CU	***Alternative A:*** Thesis II (6 CU) and Elective Courses (0 – 9 CU) ***Alternative B:*** Thesis I (2 CU) and Thesis II (6 CU)

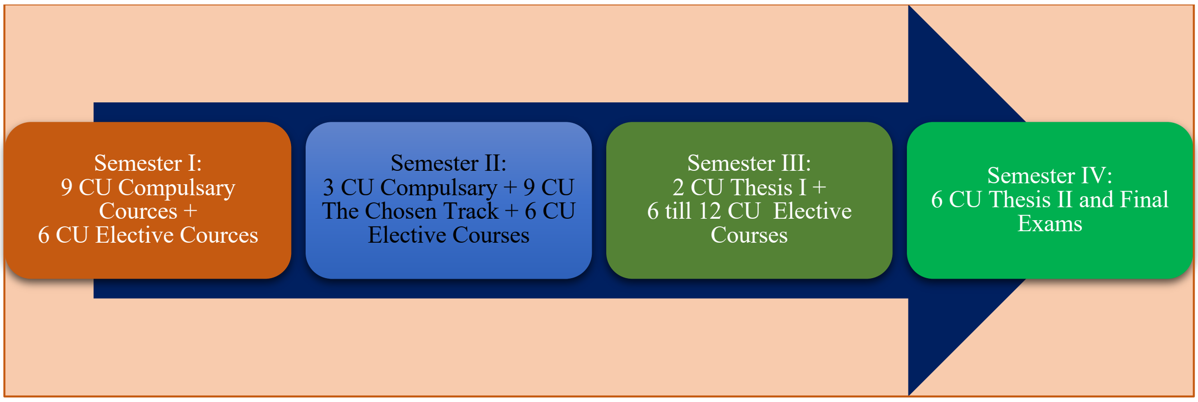

Diagram 2.11. The Diagram of The Design of Study Process

The following is the mapping between the MK and the PLO. For MK Theory and Thesis I and Thesis II, refer to Appendix I.

Table 3.12. The mapping of the course and the PLO-s

No	Code	Name of Course in English / Bhs Indonesia	CU	Research Group in Charge	Semester Offered	Status of Courses	PLO-s					
							1	2	3	4	5	6
1	MMM-5101	Analysis I	3	Analysis	1 and 2	Compulsary Course for All Students	√	√	√	√	√	
2	MMM-5102	Analysis II	3	Analysis	2	Compulsary Courses for Analysis Track	√	√	√	√		√
3	MMM-5103	Functional Analysis	3	Analysis	2	Compulsary Courses for Analysis Track	√	√	√	√	√	√
4	MMM-5106	Topology	3	Analysis	1	Compulsary Courses for Analysis Track	√	√	√	√		
5	MMM-5104	Function of One Complex Variable	3	Analysis	2	Elective Courses for Analysis Track	√	√	√	√	√	

6	MMM-5105	Euclidean Space	3	Analysis	2	Elective Courses for Analysis Track	√	√	√	√	√	√
7	MMM-5107	Real Functions	3	Analysis	2	Elective Courses for Analysis Track	√	√	√	√		
8	MMM-5108	Fixed Point Theory	3	Analysis	1	Elective Courses for Analysis Track	√		√	√	√	
9	MMM-6101	Integration Theory	3	Analysis	1	Elective Courses for Analysis Track	√		√	√	√	√
10	MMM-6102	Theory of Differential Equation	3	Analysis	1	Elective Courses for Analysis Track	√		√	√	√	√
11	MMM-6103	Sequence Spaces	3	Analysis	2	Elective Courses for Analysis Track		√	√	√		
12	MMM-6104	Operators Theory	3	Analysis	1	Elective Courses for Analysis Track		√	√	√	√	√
13	MMM-6105	Descriptive Set Theory	3	Analysis	1	Elective Courses for Analysis Track	√		√		√	
14	MMM-6108	Space of Function	3	Analysis	1	Elective Courses for Analysis Track	√	√	√			√
15	MMM-6110	Riesz Spaces	3	Analysis	2	Elective Courses for Analysis Track	√		√	√	√	
16	MMM-6111	Capita Selecta in Analysis	3	Analysis	2	Elective Courses for Analysis Track	√		√	√	√	√
17	MMM-6109	Differential Geometry	3	Analysis	1	Elective Courses for Analysis Track	√		√	√	√	
18	MMM-5201	Advanced Linear Algebra	3	Algebra	1 dan 2	Compulsary Course for All Students	√	√	√	√		√
19	MMM-	Algebraic	3	Algebra	2	Compulsary Courses for		√	√	√		

	5203	Structures				Algebra and Combinatorics Track						
20	MMM-5215	Graph Theory and Combinatorics	3	Algebra	2	Compulsary Courses for Algebra and Combinatorics Track		√	√	√	√	√
21	MMM-5216	Matrix Analysis	3	Algebra	2	Compulsary Courses for Algebra and Combinatorics Track			√	√	√	
22	MMM-5204	Module Theory	3	Algebra	2	Elective Courses for Algebra and Combinatorics Track	√		√	√	√	√
23	MMM-5206	Advanced Rings Theory	3	Algebra	2	Elective Courses for Algebra and Combinatorics Track	√		√	√	√	√
24	MMM-5207	Matrices Over Rings	3	Algebra	1	Elective Courses for Algebra and Combinatorics Track			√	√	√	
25	MMM-5210	Generalized Inverse of Matrices	3	Algebra	2	Elective Courses for Algebra and Combinatorics Track			√	√	√	
26	MMM-5212	Finite Fields	3	Algebra	1	Elective Courses for Algebra and Combinatorics Track		√	√	√	√	
27	MMM-5214	Fuzzy Logic	3	Algebra	1	Elective Courses for Algebra and Combinatorics Track		√	√	√	√	√
28	MMM-5217	Semigroup and Semiring	3	Algebra	2	Elective Courses for Algebra and Combinatorics Track		√	√	√	√	
29	MMM-	Linear System	3	Algebra	2	Elective Courses for			√	√	√	

	6202	Over Rings				Algebra and Combinatorics Track						
30	MMM-6203	Theory of Category and Functor	3	Algebra	2	Elective Courses for Algebra and Combinatorics Track	√		√	√	√	√
31	MMM-6207	Encoding Theory	3	Algebra	1	Elective Courses for Algebra and Combinatorics Track		√	√	√	√	
32	MMM-6208	Cryptography	3	Algebra	2	Elective Courses for Algebra and Combinatorics Track	√		√	√	√	√
33	MMM-6209	Algebraic Graph Theory	3	Algebra	2	Elective Courses for Algebra and Combinatorics Track		√	√	√	√	√
34	MMM-6210	Algebraic Number Theory	3	Algebra	1	Elective Courses for Algebra and Combinatorics Track		√	√		√	√
35	MMM-6211	Capita Selecta in Algebra A (Topic in Graph Theory)	3	Algebra	3	Elective Courses for Algebra and Combinatorics Track		√	√	√	√	√
36	MMM-6212	Capita Selecta in Algebra B (Topic in Algebraic Geometry)	3	Algebra	3	Elective Courses for Algebra and Combinatorics Track		√	√	√	√	
37	MMM-6213	Capita Selecta in Algebra C (Topic in Max-Plus Algebra)	3	Algebra	3	Elective Courses for Algebra and Combinatorics Track		√	√	√	√	

38	MMM-5317	Mathematical Modelling and Computation	3	Applied Mathemaatics abd Cumputational Mathematics	1 and 2	Compulsary Course for All Students		√	√	√	√	√
39	MMM-5301	Optimization Theory	3	Matematika Terapan	2	Compulsary Courses for Applied Mathematics and Computations Track		√	√	√	√	
40	MMM-5303	Differential Equations	3	Matematika Terapan	2	Compulsary Courses for Applied Mathematics and Computations Track		√	√		√	
41	MMM-5609	Applied Computational Analysis	3	Cumputational Mathematics	2	Compulsary Courses for Applied Mathematics and Computations Track			√	√	√	√
42	MMM-5608	Numerical Differential Equations	3	Cumputational Mathematics	1	Elective Courses for Applied Mathematics and Computations Track			√		√	
43	MMM-6602	Capita Selecta in Mathematics Computation	3	Cumputational Mathematics	1	Elective Courses for Applied Mathematics and Computations Track			√		√	
44	MMM-5605	Boundary Element Method	3	Cumputational Mathematics	1	Elective Courses for Applied Mathematics and Computations Track			√		√	√
45	MMM-5307	Boundary Value Problems	3	Applied Mathemaatics	2	Elective Courses for Applied Mathematics and Computations Track			√		√	
46	MMM-5309	Control Theory	3	Applied Mathem	2	Elective Courses for Applied Mathematics and		√	√		√	√

				aati cs		Computations Track						
47	MMM-5310	Advanced Operation Research	3	Applied Mathemaatics	1	Elective Courses for Applied Mathematics and Computations Track			√		√	√
48	MMM-5311	Applied Numerical Methods	3	Applied Mathemaatics	1	Elective Courses for Applied Mathematics and Computations Track			√	√	√	√
49	MMM-5312	Discrete Control Systems	3	Applied Mathemaatics	1	Elective Courses for Applied Mathematics and Computations Track		√	√		√	
50	MMM-5313	Bio Mathematics	3	Applied Mathemaatics	2	Elective Courses for Applied Mathematics and Computations Track	√		√		√	√
51	MMM-5314	Non-Linear Differential Equations	3	Applied Mathemaatics	1	Elective Courses for Applied Mathematics and Computations Track		√	√		√	
52	MMM-6301	Optimization by Vector Space Methods	3	Applied Mathemaatics	1	Elective Courses for Applied Mathematics and Computations Track			√	√	√	√
53	MMM-6303	Bifurcation Theory	3	Applied Mathemaatics	2	Elective Courses for Applied Mathematics and Computations Track		√	√		√	
54	MMM-6305	Mathematical Systems Theory	3	Applied Mathemaatics	1	Elective Courses for Applied Mathematics and Computations Track		√	√			
55	MMM-6306	Fuzzy Multi Objective Linear Programming	3	Applied Mathemaatics	1	Elective Courses for Applied Mathematics and Computations Track			√		√	√

56	MMM-6311	Bilinear System Control Theory	3	Applied Mathemaatics	1	Elective Courses for Applied Mathematics and Computations Track		√	√	√	√	√
57	MMM-6313	Model Reduction of Bilinear Systems	3	Applied Mathemaatics	2	Elective Courses for Applied Mathematics and Computations Track		√	√		√	
58	MMM-6314	Resource Allocation Optimization	3	Applied Mathemaatics	2	Elective Courses for Applied Mathematics and Computations Track			√		√	
59	MMM-6319	Capita Selecta in Applied Mathematics	3	Applied Mathemaatics	1 atau 2	Elective Courses for Applied Mathematics and Computations Track				√	√	√
60	MMM-6320	Game Theory	3	Applied Mathemaatics	2	Elective Courses for Applied Mathematics and Computations Track		√	√		√	
61	MMM-6321	Hyperbolic Differential Equation System	3	Applied Mathemaatics	2	Elective Courses for Applied Mathematics and Computations Track		√	√			√
62	MMM-6322	Logistics Systems Optimization	3	Applied Mathemaatics	1	Elective Courses for Applied Mathematics and Computations Track			√		√	
63	MMM-6323	Fractal and Its Application	3	Applied Mathemaatics	1	Elective Courses for Applied Mathematics and Computations Track			√	√	√	
64	MMM-6324	Bisimulation System Theory	3	Applied Mathemaatics	2	Elective Courses for Applied Mathematics and Computations Track			√	√	√	
65	MMM-5401	Mathematical Statistics I	3	Statistics	1 and 2	Compulsary Course for All Students		√	√	√		

66	MMM-5403	Stochastic Processes	3	Statistics	2	Compulsary Courses for Statistics and Science Data Track		√	√	√		
67	MMM-5404	Multivariate Analysis	3	Statistics	2	Compulsary Courses for Statistics and Science Data Track		√	√		√	
68	MMM-5501	Financial Mathematics	3	Statistics	2	Compulsary Courses for Statistics and Science Data Track			√		√	
69	MMM-5601	Machine Learning	3	Computational Statistics	2	Compulsary Courses for Statistics and Science Data Track		√	√		√	
70	MMM-5610	Applied Statistical Computing I	3	Computational Statistics	2	Compulsary Courses for Statistics and Science Data Track		√	√		√	√
71	MMM-5604	Business Decision Theory	3	Computational Statistics	2	Elective Courses for Statistics and Science Data Track		√	√		√	
72	MMM-6601	Capita Selecta in Statistics Computation	3	Computational Statistics	1	Elective Courses for Statistics and Science Data Track		√	√		√	
73	MMM-6604	Applied Statistical Computing II	3	Computational Statistics	3	Elective Courses for Statistics and Science Data Track		√	√		√	√
74	MMM-5513	Financial Computation	3	Statistics	2	Elective Courses for Statistics and Science Data Track			√		√	
75	MMM-5514	Financial Data Analysis	3	Statistics	1	Elective Courses for Statistics and Science Data Track			√		√	

76	MMM-5515	Modeling Bond Prices	3	Statistics	1	Elective Courses for Statistics and Science Data Track			√		√	
77	MMM-5516	Financial Modeling and the Option Price	3	Statistics	1	Elective Courses for Statistics and Science Data Track			√		√	
78	MMM-5520	Credibility Theory	3	Statistics	2	Elective Courses for Statistics and Science Data Track			√		√	
79	MMM-5402	Mathematical Statistics II	3	Statistics	2	Elective Courses for Statistics and Science Data Track		√	√	√		√
80	MMM-5406	Linear Models	3	Statistics	1	Elective Courses for Statistics and Science Data Track		√	√		√	
81	MMM-5408	Bayesian Inference	3	Statistics	2	Elective Courses for Statistics and Science Data Track		√	√		√	
82	MMM-5409	Design of Experiment	3	Statistics	1	Elective Courses for Statistics and Science Data Track		√	√	√	√	
83	MMM-5410	Econometrics	3	Statistics	2	Elective Courses for Statistics and Science Data Track			√		√	
84	MMM-5411	Time Series Analysis	3	Statistics	2	Elective Courses for Statistics and Science Data Track			√		√	
85	MMM-5412	Longitudinal Data Analysis	3	Statistics	2	Elective Courses for Statistics and Science Data Track			√		√	

86	MMM-5414	Biostatistics	3	Statistics	2	Elective Courses for Statistics and Science Data Track			√		√	
87	MMM-5415	Categorical Data Analysis	3	Statistics	1	Elective Courses for Statistics and Science Data Track			√		√	
88	MMM-5417	Semi Parametric Regression	3	Statistics	2	Elective Courses for Statistics and Science Data Track		√	√		√	
89	MMM-5419	Event History Analysis	3	Statistics	1	Elective Courses for Statistics and Science Data Track			√		√	
90	MMM-5421	Structural Models	3	Statistics	1	Elective Courses for Statistics and Science Data Track			√		√	
91	MMM-5425	Forecasting and Time Series	3	Statistics	2	Elective Courses for Statistics and Science Data Track			√		√	
92	MMM-5426	Multilevel Models	3	Statistics	1	Elective Courses for Statistics and Science Data Track			√		√	
93	MMM-5428	Capita Selecta in Statistics	3	Statistics	1	Elective Courses for Statistics and Science Data Track		√	√		√	√
94	MMM-5429	Data Mining	3	Statistics	2	Elective Courses for Statistics and Science Data Track			√		√	
95	MMM-5502	Actuarial Mathematics	3	Statistics	2	Elective Courses for Statistics and Science Data Track			√		√	

96	MMM-5503	Modeling and Risk Theory	3	Statistics	2	Elective Courses for Statistics and Science Data Track			√		√	
97	MMM-5504	Advanced Actuarial Mathematics	3	Statistics	1	Elective Courses for Statistics and Science Data Track		√	√		√	
98	MMM-5505	Mortality Table Constructions	3	Statistics	2	Elective Courses for Statistics and Science Data Track			√		√	
99	MMM-5506	Actuarial Statistics Method	3	Statistics	2	Elective Courses for Statistics and Science Data Track			√		√	
100	MMM-5508	Health Insurance	3	Statistics	1	Elective Courses for Statistics and Science Data Track			√		√	
101	MMM-5510	Financial Modeling	3	Statistics	2	Elective Courses for Statistics and Science Data Track			√		√	
102	MMM-5511	Risk Management	3	Statistics	2	Elective Courses for Statistics and Science Data Track			√		√	
103	MMM-5512	Investment Management	3	Statistics	2	Elective Courses for Statistics and Science Data Track			√		√	
104	MMM-6901	Thesis I	2	Study Program	3 or 4	Compulsary Course for All Students	√	√	√	√	√	√
105	MMM-6902	Thesis II	6	Study Program	3 or 4	Compulsary Course for All Students	√	√	√	√	√	√
Number of supported courses							23	51	104	49	93	36

K.2. By Research Track

In accordance with the provisions of UGM Chancellor Regulation no.18 of 2019 concerning the Implementation of Research-based Postgraduate Programs, the Mathematics Masters Program also opens **the Research-Based Mathematics Masters Study Program (Master by Research)**. This is not a new study program because this program has:

- Graduate profile
- Formulation of learning outcomes (Learning Outcome Program – PLO)
- Areas of interest: Analysis, Algebra, Statistics, Applied Mathematics, Actuarial, and Financial Mathematics
- Compulsory courses for study programs and a minimum of 2 (two) mandatory interests

the same as the **regular Master of Mathematics Study Program**.

The difference is only in how to achieve PLO-s, namely in the portion of the number of credits of the optional MK on the regular route, it is **replaced by research work which is marked by a series of research work and the production of reputable international publications as well as a series of work to disseminate other research results with a total of 21 credits**.

Referring to UGM Chancellor's Regulation Number 18 of 2019 and decisions at the faculty and study program level, the draft credit load for Masters in Mathematics by Research is determined as in **Table 3.13**. below:

Table 3.13 Curriculum Structure and Credit Design

Study Component	Credit	Notes	Work time plan
I.MK: Maximum 15 credits			
Study Program Compulsory Courses	9 credits	· Advanced Linear Algebra (3 credits) · Analysis I (3 credits) · Mathematical Statistics I (3 credits)	Semester I
Interest Compulsory Courses	6 credits	· 2 (two) Compulsory Interest courses each weighing 3 credits (Course name adjusts to Field / Interest taken)	Semester I
II. Thesis (8 credits)			
Thesis I (Thesis Proposal)	2 credits	· Writing Thesis Proposal and Thesis I Exam . The assessment is carried out by the Thesis I Examiner Team based on the rubric for the assessment of the Thesis I	Semester I

		examination published by PS Magister Mathematics.	
Thesis II	6 credits	· Thesis Writing and Thesis Examination II · The assessment is carried out by the Thesis II Examining Team based on the rubric of the Thesis II examination assessment published by the PS Magsiter Mathematics.	Semester II to Semester IV
III. Research and publication (minimum 21 credits)			
Research Work	5 credits	· The assessment is carried out by the Thesis Advisory Team based on the rubric of the research performance assessment published by the PS Magister Mathematics. · If there are topics that have not been covered in the Mandatory PS and Interest Compulsory Courts, the thesis supervisor team can ask students to study the selected topics that are blended in research activities by the thesis supervisor team.	Semester II to Semester IV
Pubilaction	16 SKS	· Credits and publication's mark are based on the output produced as shown in Table 2 below. · Assessed by the Assessment Team (Verification) Publications are based on the rubric for the assessment of scientific research publications published by the PS Magister Mathematics.	Semester II to Semester IV
Total	**Minimum 44 credits, maximum 50 credits**		

Notes:

- Supervisor (Thesis Supervisor concurrently Academic Supervisor) is determined at the beginning of the Semester.
- Students are expected to graduate in no more than 2 years.
- With academic considerations, a student can be transferred to the regular track

The scientific publication obligation of at least 16 credits can be fulfilled by carrying out several activities in **Table 3.14.**

Table 3.14. Number of Credits for Scientific Publication of Research

No.	Types of Research Results	credits
1.	Publication in Reputable International Journals (Scopus indexed with SJR min.0.101 or WoS-indexed with JIF min.0.05) (**a mandatory requirement to pass**)	9
2.	Publications in International Journals (Scopus indexed with SJR less than 0.101 or WoS indexed with JIF less than 0.05)	7
3.	Publication in the National Journal of S1/S2 Sinta rank	5
4.	Publications in National Journals with the rank of S3/S4/ or international journals indexed DOAJ/Copernicus/CABI/ESCII	4
5.	Publications in National Journals ranked S5/S6	3
6.	Reputable International Proceedings (Scopus indexed international proceedings)	5
7.	International proceeding	4
8.	National proceeding	3
9.	Presentation at International Seminar	3
10.	Presentation at National Seminar	2
11.	Progress report	2

The following is the mapping between the MK and the PLO. For MK Theory and Thesis I and Thesis II, refer to Appendix I.

Table 3.15
Study Plan Per Semester (in 4 Semesters) Per Student Track / Interest Choice Magister *by Research*

No	Name Of Courses	Semester	STATUS	PLO					
				1	2	3	4	5	6
SEMESTER I									
1	Analysis I (3 CU)	I	Compulsary Courses	Mapping MK dan PLO mengikuti Lampiran I					
2	Advaced Linear Algebra (3 CU)	I	Compulsary Courses						
3	Mathematical Statistics I (3 CU)	I	Compulsary Courses						

4	Mathematical Modelling and Computation (3 CU)	I	Compulsary Courses						
5	Maximum 1 Elective Courses Choosen from the list (3 CU)	I	MK Pilihan						
5	Thesis I (2 CU)	I	Compulsary Courses						
Total Semester I		17 CY							
SEMESTER II till IV									
6	Theisi II (6 CU)	II sd IV	Compulsary Courses						
7	Research Work (5 CU)	II sd IV	Compulsary Courses	√	√	√	√	√	√
8	Publication (16 CU s.d. 22 CU)	II sd IV	Compulsary Courses	√	√	√	√	√	√
Total Semester II s.d. IV		27 CU s.d. 33 SKS							

The amount of CU taken after the first semester is determined by the previous semester's GPA.
● If the semester GPA is less than 3.00 then the maximum MK is 12 credits.
● If the semester GPA is greater than 3.00, the maximum MK will be taken at 17 CU (for the Masters by Research Program).

The list of courses can be seen in Point N. The meaning of course codes can be seen in the Appendix, while the course syllabus can be seen in Appendix II.
The list of courses can be seen in Appendix I. The meaning of course codes can be seen in Appendix II. The course syllabus can be seen in Appendix III.

L Final Project (Thesis I and Thesis II)

The thesis is a student's final assignment and is one of the graduation requirements. Students can take Thesis I starting in semester III. Registration of proposals from thesis supervisors is carried out at the end of the second semester via the online form provided by the Study Program. The determination of the thesis supervisor is carried out through a laboratory meeting. In working on their thesis, students are supervised by one or two lecturers. The Thesis Supervisor will also act as an Academic Supervisor (DPA) since the semester the thesis begins.

The Thesis I Examination is carried out no later than 1 (one) year after taking the Thesis I course. Requirements for students to submit the Thesis I Examination:

- Have attended a Thesis writing workshop organized by the Study Program.
- Obtain DPA approval which is stated by a certificate from the supervisor that the thesis is ready to be submitted. The Certificate

Form is provided by the Study Program or can be downloaded from the Study Program website.

The Thesis I Examination Examining Team consists of a supervisor plus 2 (two) examining lecturers according to their field of interest. The Thesis I examination can be declared passed if the average score of the examining team is at least 3.00. If a student is declared to have passed with revisions, the Thesis I revision limit is set at a maximum of 2 (two) months from the time it is tested. If within a period of 2 (two) months, the student has not completed the revision, then the Study Program will coordinate with the examining team to extend the revision period or propose a re-examination to the Study Program. If a student is declared not to have passed, a re-examination will be held after the student submits registration to the Study Program.

Thesis II can be taken by students after being declared to have passed the Thesis I exam or at the same time as taking Thesis I, if in one semester students can take Thesis I and Thesis II exams. The Thesis II examination will be carried out no sooner than 2 (two) months after the Thesis I examination. Requirements for students to submit the Thesis II examination:

- Obtain DPA approval which is stated by a certificate from the supervisor that the thesis is ready to be submitted.
- Minimum GPA of 3.25 after cancellation of course grades (if any courses are cancelled) without C-, C/D, D+, D and E grades.
- Have submitted a publication manuscript to a journal recognized by the Study Program or a presentation at a national or international seminar as demonstrated by proof of submission or certificate.
- Attach the Thesis I manuscript which has been revised by a number of examining lecturers.

The Thesis II Exam Examining Team consists of the Thesis I Examining lecturer plus 1 (one) non-interested examining lecturer. The Thesis II examination can be declared passed if the average score of the examining team is at least 3.00. If the student is declared to have passed with revisions, then the revision limit for Thesis II is set at 2 (two) months from the time it is tested. If within a period of two months, the student has not completed the revision, a re-examination will be held after the student submits registration to the Study Program. If a student is declared not to have passed, a re-examination will be held after the student submits registration to the Study Program.

M Transition Regulation

Students before the class of 2022/2023 follow the transition rules and provisions as follows:

1. If a student repeats a course whose status changes from mandatory interest to elective or vice versa, then the status of the course is in accordance with the curriculum when the student enters.
2. All courses taken from the 2017 Curriculum are still recognized. If a student repeats a course that has an equivalent, a new code is used. **Table 3.16** shows course equivalencies.

Table 3.16. The List Of Equivalent Courses

Course Codes in the 2017 Curriculum	Course Names in the 2017 Curriculum	Course Codes in the 2022 Curriculum	Course Names in the 2022 Curriculum
MMM 5302	Mathematical Modelling	MMM 5317	Mathematical Modelling and Computation
MMM 6302	Dinamical Game Theory	MMM 6320	Game Theory
MMM 6309	Hyperbolic Systems	MMM 6321	Systems of Hyperbolic Differential Equations
MMM 6318	Logistics Design Optimization	MMM 6322	Logistics System Optimization
MMM 6603	Advanced Mathematical Computation	MMM 5609	Applied Computational Analysis
MMM 6204	Graph Theory	MMM 5215	Graph Theory and Combinatorics
MMM 5202	Semigroups	MMM 5217	Semigroups and Semirings
MMM 5211	Matrix Theory	MMM 5216	Matrix Analysis
MMM 5407	Sampling Theory	MMM 5409	Experimental design
MMM 5422	Data Simulation and Bootstrapping	MMM 5601	Machine Learning
MMM 5602	Applied Statistical Computing	MMM 5610	Applied Statistical Computing I

N Learning Methods

The learning method in the Master of Mathematics Study Program was developed from the 'Patrap Triloka' educational philosophy (Ing ngarso sung tulodho, Ing madyo mangun karso, Tut wuri handayani or in the front being an example, in the middle motivating, and in the back providing support). Lecturers in the context of "Patrap Triloka" position themselves as figures who are expected to be able to be role models, encouragement, mentors, learning partners and directors who are authoritative and friendly with their students. This philosophy can be translated as a learning process based on partnerships between lecturers and students to create a comfortable, active, creative and innovative academic atmosphere. This learning program is called Student Teacher Aesthetic Role-sharing (STAR). In principle, in its implementation, this learning program is designed to create: (a) communication and consultation forums between lecturers and students; (b) a vehicle for improving skills and scientific insight; and (c) a forum for developing student scientific inspiration and ideas. The learning process itself refers to the handbook module. Monitoring and evaluation of learning programs and processes (substance, methods, atmosphere and learning instruments) is carried out through individual and group assignments, exams and presentations.

O Assesment Method

1. For courses: Advanced Linear Algebra, Analysis I, Mathematical Statistics I, Mathematical and Computational Modeling, and Elective MK, the assessment method follows the provisions set out in the handbooks module.
2. For hesis I and Thesis II, assessment is based on exams carried out by a team of examiners appointed by the Study Program using the rubric published by PS.
3. For research work activities and scientific publications, assessment follows the assessment rubric published by the Study Program.

P Graduation Requirements

Students can be declared passed in the Regular Masters program if they meet the following conditions:

1. Has taken a minimum of 44 credits and a maximum of 50 credits.
2. Cumulative GPA ≥ 3.25 after cancellation of course grades (if any courses are cancelled) without D and E grades.
3. The minimum score of Thesis I and Thesis II is B.
4. Have a minimum TOEFL score of 450 (AcEPT 209) and a minimum TPA/PAPS of 500 (as a graduation requirement). TOEFL/TPA scores (or equivalent) are valid while taking the Masters study program.
5. The thesis manuscript accompanied by the publication text has been approved by the supervisor and the team of examiners.

Additional requirements for passing the Masters by Research program are having one paper published in a reputable international journal.

Q Quality Assurance on Study Program Level

The quality assurance process is carried out following the Internal Quality Assurance System in higher education consisting of 5 stages, namely Determination, Implementation, Evaluation, Control and Improvement (PPEPP) as explained in section 1.9. This cycle is to ensure continuous improvement in the educational process in the Master of Mathematics Study Program. Continuous improvements are carried out by the Mathematics Department through the Management Review Meeting (RTM) forum conducted by the Mathematics

Department together with the department level quality assurance team to hear the overall evaluation results. Responses to input can be divided into several things:

1. responses that can be handled directly by the Study Program, Laboratory or Department related to their main tasks;
2. responses that require deliberation from all members of the Department Working Meeting (RKD) or all Mathematics Department lecturers, for example regarding the Department's stance on a condition;
3. responses in the form of suggestions and input to the Faculty are submitted at the Faculty Working Meeting (RKF), for example regarding information systems, Faculty infrastructure, implementation of Faculty policies, etc.;
4. Responses regarding proposals for University level matters are submitted at the RKF or Academic Senate Meeting, with the hope that the University can convey them through appropriate channels.

Improving learning management which has an impact on ensuring the quality of learning outcomes has been implemented through a monitoring process and providing feedback to students in direct form through discussions between lecturers and students in the Semester Coordination Team (TKS) forum formed by the Department for each Study Program for each academic level. . The TKS Team is an SPMI team at the study program level determined by the Dean's Decree at the suggestion of the Department of Mathematics. The TKS Team consists of lecturers and students who represent students per year group. Inputs from the TKS team will become input for study program managers, department managers and faculty managers for a continuous improvement process (quality assurance process). The results of TKS monitoring and evaluation at the TKS Meeting are submitted to the relevant study programs and departments for follow-up. One of the parameters in measuring the quality standards of each study program in the Department of Mathematics is to use parameters in the form of the quality of the libraries (textbooks) used in lectures. The quality standards of study programs are also measured by the number of publications by Permanent Study Program Lecturers (DTPS) in international journals, and the number of DTPS who carry out academic and research activities outside the University, both at home and abroad, such as being invited speakers, becoming lecturers. guest, being a lecturer examining a thesis or dissertation, and so on. This will support and improve the quality of the teaching and learning process and the success of graduates of the Mathematics, Statistics, Actuarial Science, Masters in Mathematics and Doctor of Mathematics Study Programs. The results of the internal evaluation each semester are used to improve the learning process in the following semester, which leads to the development of the study program curriculum. External evaluation by the National Accreditation Board for Higher Education (BAN PT) is always carried out and the results are very satisfactory as shown by the accreditation results. External recognition is also realized through the establishment of cooperation and partnerships in the form of collaborative research in the WCP (world class professor) grant scheme with various LN partners, and the establishment of educational KS with the University of Twente - The Netherlands, University of Kanazawa, Japan, University of Waterloo – Canada , University of Vienna – Austria. Another form of external recognition is the collaboration of research workshops with CIMPA France in the form of CIMPA Schools and SEAMS Schools with various universities in Europe and ASEAN with partial funding from CIMPA. The results obtained are used to improve the curriculum, learning processes and handling of supporting infrastructure and facilities, as well as improving the administration system, which is supported by continuous research. Collaborative activities with partners include colloquiums, workshops for research development and learning processes. The overall organizational structure of quality assurance at the university, faculty, department and study program levels is given in Figure 2.1.

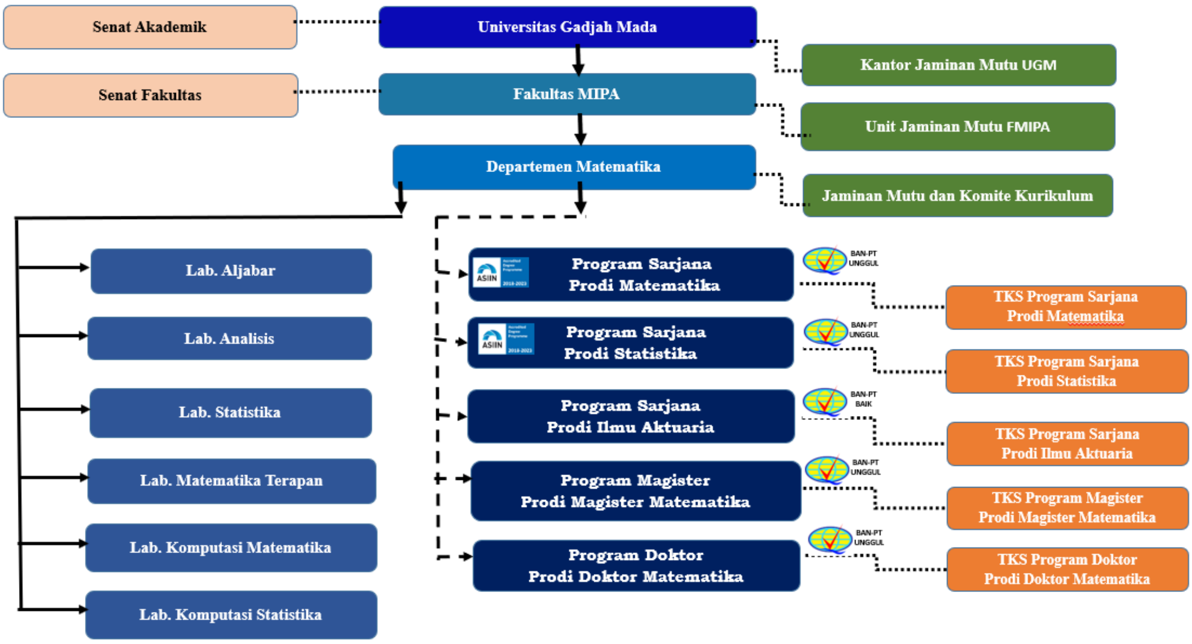

Figure 3.17. Quality Assurance Organizational Structure of the Master of Mathematics Study Program

R Other Provisions

1. The Thesis Examining Team I consists of an advisor and 2 examiners who have the same field of knowledge as the thesis topic.
2. The Thesis II Examining Team consists of the Thesis I Examining Team plus 1 examiner from outside the field. In the event that the Thesis I Examiner Team who is not the supervisor is permanently absent, it is possible for the person concerned to be replaced by another examiner.
3. The assessment team for research results in the form of scientific publications consists of a supervisor and 2 assessors who have the same field of knowledge as the research results.

S Additional Provisions:

1. Students may apply to replace a research result with another research result that has a better CU and value.

Cancellation of courses in the form of research results of a maximum of 10% of the total CU achieveds

COURSE SYLLABUS IN ANALYSIS LABORATORY
(17 COURSES)

MMM 5101 ANALYSIS I (3 CU)

PREREQUISITES

Students are required to have good understanding on the real number system.

LEARNING OUTCOMES

After completing this course, the students should have the ability to:

CO 1. prove properties and solve problems related to metric spaces and topological concepts on metric spaces

CO 2. prove properties and solve problems related to sequences, complete spaces, and continuous functions

CO 3. prove some characteristics and solve problems related to compactness

CO 4. solve problems related to Baire category and Ascoli-Arzela Theorem

SYLLABUS

Metric spaces, topological concept on metric spaces (neighbourhood, open sets, closure of sets, closed sets, subspace, separability). Sequences in metric spaces. Complete metric spaces. Continuous and uniformly continuous functions. Compact metric spaces (Compact sets, finite intersection property, totally bounded, Bolzano-Weierstrass property, sequentially compact). Baire category, sequences of functions and Ascoli-Arzela theorem. Topological spaces (some basic notions).

REFERENCES

1. Royden, H. L., and Patrick Fitzpatrick, 2010, Real analysis (4th Edition), Prentice-Hall Inc, New Jersey.
2. Bruckner A.M, Bruckner J.B., Thomson B.S., 1997, Real Analysis, Prentice-Hall Inc.
3. Copson E.T., 1968, Metric Spaces, Cambridge at The University Press.
4. Hewitt E., Stromberg K., 1969, Real and abstract Analysis, Springer-verlag.

MMM 5102 ANALYSIS II (3 CU)

PREREQUISITES

Students have taken the course of Analysis I and have participated in the final exam of the course.

LEARNING OUTCOMES

After completing this course the students have ability to :

CO 1. Analyze the measurability of a set and a function.

CO 2. Analyze the Lebesgue integrability of a function on a measurabl set and prove some properties of Lebesgue integrable functions.

CO 3. Evaluate the general measurable sets and function and prove some properties of general integrable function

SYLLABUS

1. Measure: length of an interval and outer measure of a set.
2. Measurable set: definition of measurable sets, properties of measurable sets, and Lebesgue measure.
3. Non-measurable set.
4. Measurable function: definition of measurable functions, some properties of measurable functions, operations of measurable functions, step functions, and simple functions.
5. The Lebesgue Integral: definition of the Lebesgue integral on a measurable set, relation between the Riemann integral and the Lebesgue integral on [a, b], some properties of the Lebesgue integral.
6. General measure and general integration: definition and properties of general measure and general measurable function, general integration over a general measurable set, and Radon Nikodym theorem.

REFERENCES

1. Royden, H.L. and Fitzpatrick, P., 1988. *Real analysis* (Vol. 32). New York: Macmillan.
2. Wheeden, R.L. and Zygmund, A., 1977. Measure and integration.
3. Jain, P.K., Jain, P.K. and Gupta, V.P., 1986. *Lebesgue measure and integration*. John Wiley & Sons.

MMM 5103 FUNCTIONAL ANALYSIS(3 CU)

PREREQUISITES

Students have taken Analysis I and have participated in the final exam of the course. Students also have some basic theory in algebra, especially vector space, linear independence set, and orthonormal basis.

LEARNING OUTCOMES

After completing this course, the students should have the ability to:

CO 1. prove some properties of continuous linear mapping and its norm

CO 2. prove some characteristic subsets of a Hilbert space based on its inner product and continuous linear mapping

CO 3. justify properties of some operators, especially projection, selfadjoint, and normal operators

CO 4. justify and make use of some characteristics of completely continuous operator and proper value

SYLLABUS

1. Banach space: definition of Banach space, continuous linear mapping and its norm, dual space.

2. Hilbert space: definition of Hilbert space, orthonormal basis, separable space, Riesz representation theorem
3. Operators in Hilbert space: bilinear and sesquilinear mappings, adjoint of an operator, some types of operators (adjoint operator, projection operator, isometric operator, unitary operator, normal operator), invariant and reducing space.
4. Spectral Theorem: proper value, approximate proper value, ccoperator, spectral theorem of normal operator.

REFERENCES

1. Berberian, S.K., 1999, *Introduction to Hilbert space* Vol. 287, American Mathematical Soc.
2. Kreyszig, E., 1991. *Introductory functional analysis with applications* (Vol. 17), John Wiley & Sons.
3. Bachman, G. and Narici, L., 2012, *Functional Analysis*, Dover Publications.
4. Conway, J.B., 2019, *A Course in Functional Analysis*, Springer Verlag, New York.
5. Taylor, A.E., 1980, *Introduction to Functional Analysis*, John Wiley and Sons, New York.

MMM 5104 THEORY OF COMPLEX FUNCTIONS (3 CU)
PREREQUISITES -

LEARNING OUTCOMES

After completing this course the students are expected to be able:

CO 1. to understand and prove or solve theories related to complex integral.

CO 2. to understand and prove or solve theories related to Laurent series, power series, and their properties.

CO 3. to understand and prove or solve theories related to poles, residues, and their applications.

CO 4. to understand and prove or solve theories related to conformal mapping and their properties.

SYLLABUS

Open Mapping Theorem, complex integral, antiderivative of holomorphic function, Cauchy's Theorem, Cauchy's Integral Formula, Derivative of Analytic function, Maximum Modulus Principle, Laurent series, Power series, isolated singular point, residues and poles, essential singular point, improper Integral, inverse of Laplace transform, Roche's Theorem, Conformal mapping.

REFERENCES

1. Serge Lang, 1999, *Complex Analysis, Fourth Edition,* Springer-Verlag New York, Inc.
2. Stein, E.M. and Shakarchi, R., 2003, *Complex Analysis*, Princeton University Press.

MMM-5105 EUCLIDEAN SPACE (3 CU)
PREREQUISITES
Students have learned real analysis and metrix space.

LEARNING OUTCOMES
After completing this course the students have ability to:
CO 1. generalize some concepts in real system in Euclidean space and justify some concepts in Euclidean space which do not hold in metric spaces.
CO 2. prove and apply theories of derivative.

SYLLABUS
1. Topology on $\mathfrak{R}^n$: open set, connected set, compactness and their characteristics.
2. Convergence and continuity in $\mathfrak{R}^n$: convergence sequence, Cauchy sequence, some characteristics of continuous function in convergence sequence and open sets. Continuous functions on compact sets and on connected sets.
3. Derivative in $\mathfrak{R}^n$: Fréchet and Gâteaux derivatives and its relation,mean value theorems,
4. Applications of derivative in $\mathfrak{R}^n$:surjective mapping theorem, inverse mapping theorem, and its application in optimization

REFERENCES
1. Bartle, R.G., 1976, *The Element of Real Analysis*, second edition, John Wiley and Sons, New York.
2. Duistermaat, J.J. and Kolk, J.A.C., 2004, *Multidimensional Real Analysis I: Differentiation*, Cambridge University Press, United Kingdom.

MMM 5106 TOPOLOGY (3 CU)
PREREQUISITES
Students have understood the basic properties of set and real number system.

LEARNING OUTCOMES
On successful completion of this course, students should be able to:
CO 1. use properties of some topological concepts to prove their advanced properties.
CO 2. characterize spaces using axioms of separation
CO 3. prove some characteristics of continuous functions and some convergence theorems
CO 4. prove some properties of compactness and connectedness.

SYLLABUS
1. General topological structures: definition of topology space, open set, closed set, bases, sub-bases, subspace, cartesian products.
2. Axioms of separation, continuous maps, open maps and closed maps, homeomorphism

3. Convergence in topological spaces: nets and filters.
4. Subspaces, sums, cartesian products, and quotient spaces
5. Compactness and connectedness.

REFERENCES

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2. Dugundji J., 1996, Topology, Allyn and Bacon Inc. Boston.
3. Munkres J.R., 2013, Topology: Pearson New International Edition, Pearson.
4. Kelley J.L., 1975, General Topology, Springer-Verlag, New York.

MMM 5107 REAL FUNCTIONS(3 CU)

PREREQUISITES

Students have taken the module of Analysis I (MMM-5101) and have participated in the final exam of the module.

LEARNING OUTCOMES

After completing this course, the students should have:

CO 1. Ability to prove properties and solve problems related to limit superior and limit inferior of a function.

CO 2. Ability to prove properties and solve problems related to semi-continuous functions.

CO 3. Ability to analyze, prove, and solve problems related to properties and characterization of Baire-1 functions.

CO 4. Ability to solve problem related to Darboux functions and use the properties of Darboux functions to solve problems in mathematical analysis.

SYLLABUS

1. Limit superior and limit inferior of real functions.
2. Semi-continuous functions : the definition, properties, and characterization of upper and lower semi-continuous functions.
3. Baire class on functions : the classical definition and basic properties of Baire-1 functions, uniform limit of sequences of Baire-1 functions, and some characterization of Baire-1 functions.
4. Darboux functions : some properties of Darboux functions, characterization of Darboux functions, and some Darboux functions which are continuous.

REFERENCES

1. Mc Shane E.J., 1961, *Integration*, Princeton University Press.
2. Kharazishvili A., 2018, *Strange Functions in Real Analysis*, third edition, Chapman & Hall Book, Boca Raton.
3. Gordon R.A.,1994, The integrals of Lebesgue, Denjoy, Perron and Henstock, American Mathematical Society.

4. Natanson I.P., 1964, *Theory of Functions of a Real Variable*, Vol 1 and 2, Frederick Ungar Publishing Co, New York.
5. Bruckner A.M., Bruckner J.B., and Thomson B.S., 2008, *Real Analysis*, second edition, Prentice-Hall Inc, New Jersey.
6. Lee P.Y., Tang W.-K., and Zhao D., 2001, An equivalent definition of functions of the first Baire class, *Proc. Amer. Math. Soc.*, 129, 2273-2275.
7. Goffman C., 1953, *Real Functions*, Holt, Rinehart and Winston, New York.

MMM 5108 FIXED POINT THEORY (3 CU)

PREREQUISITES

Before taking this course, students must have a good understanding about metric spaces, Banach spaces, and Hilbert spaces.

LEARNING OUTCOMES

After completing this course, the students should have:

CO 1. ability to prove properties related to contraction mappings;

CO 2. ability to prove fixed point theorems related to non-expansive mappings;

CO 3. ability to use continuation methods to prove fixed point theorems for contractive and non-expansive mappings;

CO 4. ability to prove properties related to the theorems of Brouwer, Schauder, and Mönch

SYLLABUS

Contraction mappings on metric spaces; Banach's contraction principle; theorems related to contraction mappings on metric spaces.

Non-expansive mappings; fixed point theorems related to nonexpansive mappings.

Continuation methods for contractive and non-expansive mappings.

The theorems of Brouwer, Schauder, and Mönch.

REFERENCES

1. Agarwal, Ravi P. Meehan, Maria. and O'Regan, Donal. 2001, *Fixed Point Theory and Applications*, Cambridge University Press, United Kingdom.
2. Dugundji, James. and Granas, Andrzej. 1982, *Fixed Point Theory*, Monografie
3. Matematyczne,Vol 16, Polish Scientific Publishers.
4. Khamsi M.A., and Kirk, W., 2001, *An Introduction to Metric Spaces and Fixed Point Theory*, John Wiley & Sons. Inc, New York.

MMM 5109 THEORY OF DIFFERENTIAL EQUATION (3 CU)

PREREQUISITES

Students have taken the module of Analysis I (completeness, compactness, continuous function, and Arzelà-Ascoli Theorem) and have participated in the final exam of the module. Students have some knowledge in Linear Algebra: independence linear, bases, and matrix.

LEARNING OUTCOMES

After completing this course the students have ability to:

CO 1. prove theorems of analysis which are used in proving the existence and uniqueness of the solution of differential equations.

CO 2. prove the existence and uniqueness of the solution of initial value problem and system of differential equations with initial conditions.

CO 3. Prove and justify the characteristic of solution of differential equations and systems.

SYLLABUS

1. Some theories in analysis: compactness in C(K) and Banach Fixed PointTheorem.
2. Differential equation of order one: Peano Theorem, existence and uniqueness of the solution of initial value problem, Picard Theorem, approximation solution, and extension of the solution.
3. System of differential equations-vector approach: existence and properties of solutions, system of higher order.
4. Linear system of differential equations-matrix approach:
   i. General linear system: fundamental system, Reduction of order, Nonhomogeneous system.
   ii. Linear Equation of higher order: fundamental system, Wronsky determinant, Reduction of order, Nonhomogeneous system, Green's function.
   iii. Linear system with constant coefficients: characteristic value and vector characteristic, general solution, homogeneous equation of n^{th} order, and their applications.

REFERENCES

1. Witold Hurewicz, 1958, *Lectures on Ordinary Differential Equations*, The Technology Press of Massachusetts Institute of Technology and John Wiley & Sons. Inc., New York.
2. Earl A. Coddington and Norman Levinson, 1955, *Theory of ordinary differential equations*, McGraw-Hill Book Company, Inc., New York-Toronto-London.
3. Earl A. Coddington and Robert Carlson, 1997, *Linear ordinary differential equations*, SIAMS, Philadelphia.
4. Royden, H.L. and Fitzpatrick, Real Analysis, Fourth Edition, English reprint edition copyright @ 2010 by Pearson Education Asia Limited and China Machine Press, 2010.

5. Teschl, G., 2012, *Ordinary Differential Equations and Dynamical Systems*, Graduate Studies in Mathematics, Volume 140, American Mathematical Society, Providence.

MMM 6101 THEORY OF INTEGRAL (3 CU)
PREREQUISITES
Student has learned the Riemann integral. It will be better if the student has learned the Lebesgue integral.

LEARNING OUTCOMES
After completing this course the students have ability to:
CO 1. prove and develop some properties of (non-absolute) integral.
CO 2. justify and develop some convergence theorems of the integral.

SYLLABUS
1. Motivation: Absolute and non-absolute integrals.
2. Gauge functions, generalized absolutely continuous functions, generalized bounded variation functions.
3. Definition and some characteristics of non-absolute integrable functions.
4. Some convergence theorems of the associated integralsMotivasi: Integral mutlak.

REFERENCES
1. Lee Peng Yee, 1989, *Lanzhou Lectures on Henstock integration*, World Scientific, Singapore.
2. Lee P.Y. and Výborný, R., 2000, Integral: *An Easy Approach after Kurzweil and Henstock*, Cambridge University Press.
3. Bartle, R.G., 2001, A Modern Theory of Integration, Graduate Studies in Mathematics Vol 32, reprinting, American Mathematical Society, Providence, Rhode Island.
4. Pfeffer, W.F., 1993, *The Riemann Approach to Integration*, Cambridge University Press, New-York, USA.
5. Indrati, Ch. R., 2003, Convergence Theorems for the Henstock Integral Involving Small Riemann Sums, *Real Analysis*.

MMM 6103 SEQUENCE SPACES (3 CU)
PREREQUISITES
Students are required to have taken Analysis I

LEARNING OUTCOMES
On successful completion of this course, students should be able to:
CO 1: analyze the spaces of ℓ^p , $1 \le p \le \infty$, and their properties.
CO 2: analyze difference sequence space and their properties.
CO 3: analyze Orlicz sequence spaces and their properties.

SYLLABUS

The course will cover several types of sequence spaces, namely ℓ^p spaces ($1 \le p \le \infty$), c *and* c_0 spaces, difference sequence space, $c(\Delta)$ *and* $c_0(\Delta)$ spaces, and Orlicz sequence spaces, and their properties.

REFERENCES

1. Lindenstrauss, Joram and Tzafriri, Lior., 1977, *Classical Banach Spaces I – Sequence Spaces*, Springer-Verlag Berlin Heidelberg New York.
2. Musielak, Julian., 1983, *Orlicz Spaces and Modular Space*, Lecture Notes in Mathematics, vol 1034, Springer, Berlin, Heidelberg.

MMM 6104 OPERATOR THEORY (3 CU)

PREREQUISITES -

LEARNING OUTCOMES

On successful completion of this course, students should be able to:

CO 1. understand and prove any problem related to linear operators.

CO 2. understand and prove any problem related to adjoint operators.

CO 3. understand and prove any problem related to closed linear operators.

SYLLABUS

Introductions: preview in Hilbert Spaces. Linear operators and their adjoints: basic notions, bounded linear operators and functionals, Isometry and isomorphism, adjoint operators, Banach-Steinhaus' Theorem, Strong and Weak Convergence, Projections, unitary operators. Closed Linear Operators: Closed and closable operators, Closed Graph Theorem, Spectral Theory, Symmetry and self-adjoint operators, normal operators.

REFERENCES

1. Weidmann, Joachim., 1980, *Linear Operators in Hilbert Spaces*, Springer-Verlag New York Inc.
2. Conway, John B., 1990, *A Course in Functional Analysis*, Second Edition, Springer-Verlag New York Inc.

MMM 6105 DESCRIPTIVE SET THEORY(3 CU)

PREREQUISITES

Students have taken the module of Analysis I (MMM-5101) and have participated in the final exam of the module. Before taking this course, students must have a good understanding about metric spaces and topology.

LEARNING OUTCOMES

After completing this course, the students should have:

CO 1. Ability to analyze and prove properties of metrizable spaces and Polish spaces.

CO 2. Ability to analyze and prove properties related to functions on metrizable spaces.

CO 3. Ability to analyze and prove properties of Borel sets in a topological space.

CO 4. Ability to analyze and prove properties related to analytic sets.

SYLLABUS

1. Ordinal and cardinal numbers : well-ordered sets, ordinal numbers, cardinal numbers.
2. Metrizable spaces and Polish spaces : metrizable spaces, trees, Polish spaces, extensions of continuous functions and homeomorphism on metrizable spaces, Polish subspaces of Polish spaces, Hilbert cube, Vietoris topology, Cantor-Bendixson derivatives, zero-dimensional spaces.
3. Borel sets : The Borel Hierarchy, standart Borel spaces.
4. Analytic sets : Representations of analytic sets, separations theorems

REFERENCES

1. Kechris A.S., 1994, *Classical Descriptive Set Theory*, Springer-Verlag, Berlin.
2. Srivastava S.M., 1998, *A course on Borel Sets*, Springer-Verlag, New York.
3. Dugundji J., 1966, *Topology*, Allyn and Bacon. Inc, Boston.

MMM 6108 FUNCTION SPACE (3 CU)

PREREQUISITES

Students have taken the course of Analysis I and have participated in the final exam of the course.

LEARNING OUTCOMES

After completing this course the students have ability to:

CO 1. determine of bounded variation functions and absolutely continuous functions.

CO 2. prove some theorems of the Lebesgue spaces.

CO 3. analyze and prove some properties related to the spaces of funtions defined by an Orlicz function.

SYLLABUS

1. Spaces of bounded variation and absolutely continuous functions
2. The Lebesgue spaces: norm space, L^p space
3. An Orlicz function and its properties.
4. The spaces of funtions defined by an Orlicz function

REFERENCES

1. Musielak, J., 2006. *Orlicz spaces and modular spaces* (Vol. 1034). Springer.
2. Royden, H.L. and Fitzpatrick, P., 1988. *Real analysis* (Vol. 32). New York: Macmillan.

3. Rao, M.M., and Ren, Z. D., 2002. Pure and Applied Mathematics: A series of Monograph and Textbooks, Application of Orlicz Spaces. New York: Marcel Dekker, Inc.

MMM 6110 RIESZ SPACE(3 CU)
PREREQUISITES
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LEARNING OUTCOMES
After completing this course, the students should be able to:
CO 1. prove basic properties of Riesz spaces.
CO 2. analyze several types of Riesz spaces/subspaces and prove their properties.
CO 3. determine order convergence or uniform convergence of sequences on Riesz spaces.
CO 4. solve problems related to norm Riesz spaces and Banach lattices.

SYLLABUS
The course will cover basic concepts and properties of Riesz spaces:
1. Riesz Spaces
2. Ideals, Bands, and Disjointness
3. Archimedean Riesz spaces, Order Convergence, and Uniform Convergence
4. Projection Bands and Dedekind Completeness
5. Norm Riesz Spaces and Banach Lattices
6. The Riesz-Fischer Property and Order Continuous Norms

REFERENCES
1. Zaanen, A.C., 1997, Introduction to Operator Theory in Riesz Spaces, Springer.
2. Luxemburg, W.A.J., dan Zaanen, A.C., 1971, Riesz Spaces, American Elsevier Pub. Co.
3. Meyer-Nieberg, 1991, Banach Lattices, Springer.
4. Aliprantis, C. dan Burkinshaw, O., 2006, Positive Operators, Springer.
5. Kalauch, A. dan Onno van Gaans, 2019, Pre-Riesz Spaces, De Gyuter.

MMM 6109 DIFFERENTIAL GEOMETRY (3 CU)
PREREQUISITES
Before taking this course, the students must have a good understanding about the concept of the Differential Equations and Multivariable Calculus

LEARNING OUTCOMES
After completing this course, the students should have:
CO 1. Ability to analyse the cases of tangent space and differential form.
CO 2. Ability to calculate the case of Frenèt Formula and frame field.
CO 3. Ability to analyze Isometry on $\mathbb{R}^3$.
CO 4. Ability to analyze the case of surface in $\mathbb{R}^3$ and manifolds.

SYLLABUS

a. Tangent Space and Differential Forms

b. Frenet Formula and Frame Fields

c. Isometry on $\mathbb{R}^3$.

d. Surface in $\mathbb{R}^3$ and Manifolds

REFERENCES

1. O'Neill, B., 2006, Elementary Differential Geometry, Elsevier.
2. Rudolph G, Schmidt, M., 2013, Differential Geometry and Mathematical Physics (Part I. Manifolds, Lie Groups, and Hamiltonian Systems), Springer.

MMM 6111 CAPITA SELECTA IN ANALYSIS (3 CU)

PREREQUISITES

Students are required to be proficient at abstract analysis.

LEARNING OUTCOMES

After completing this course, the students should have the ability to

CO1. demonstrate knowledge of the given subject

CO2. analyze the relation of the given subject to another knowledge

SILABUS

Content of this course may vary every year depends on the lecturer's Expertise.

REFERENCES

Decided every year, depending on the lecturer's expertise.

COURSE SYLLABUS IN ALGEBRA LABORATORY (20 COURSES)

MMM 5201 ADVANCED LINEAR ALGEBRA (3 CU)

PREREQUISITES

1. Students should be familiar to elementary logic and basic mathematical notions, such as sets, maps, equivalence relations, etc.

2. Students should have knowledge of basic concepts of matrix algebra, such as vectors, matrices, and how to compute with them;

LEARNING OUTCOMES

On successful completion of this course, students should be able to:

CO 1: identify, describe, and apply fundamental concepts of linear algebra, consisting abstract vector space over general field, linear independence, generator, basis, dimension (including the infinite one). Direct sum and linear transformations/operators, vector space of linear transformations, and dual space of a given vector space; and relate the calculations of linear transformations to that of matrices by choosing particular basis for diagonalization of a square matrix under appropriate conditions.

CO 2: identify, describe, and apply the notions of inner product space over field of complex number and construct an orthonormal basis for an inner product space. Construct the adjoints of operators. Linear operators on inner product space: adjoints of operators, orthogonal/unitary operators, orthogonal/unitary diagonalization of self-adjoint/normal operators, symmetric bilinear form and quadratic form.

CO 3: develop specific mathematical skills, competencies and thought processes sufficient to support further study or work in this or related fields (especially skill on abstraction, generalization, and analogy), construct rigorous mathematical proofs and counter examples.

SYLLABUS

The study material for Advanced Linear Algebra can be divided into 2 groups, namely the Abstract Vector Space and the Inner Product Space.

A. Abstract Vector Space over Any Field (before mid exam)

Vector Spaces, Subspace, Existence of Bases (Generator, Linear-independent, Base including Infinite Dimensions), Product (Product), Direct Sum (including infinite index), Linear Transformation (Kernel, Image, Rank, Rank and Nullity Theorem), Vector Space of all linear transformations, Composition linear transformations, and inverse linear transformations, Matrix Representation of Linear Transformations. Base Change (Equivalence Relationship and Similarity Relation of two matrices), Linear Transformation Vector Space Isomorphism and Matrix Vector Space, Eigenvalue and Eigen Vector Linear Transformation, and Diagonalization, Dual Space, basis dual space, and isomorphism of vector space and dual space of its dual space .

B. Inner Product Space over the complex number field C (after mid exam)

Inner Product, Inner Product Space (IPS), Norm, Angle and Distance of two Vectors, Orthogonality, Orthonormal Basis, and Their Properties, Matrix of Representation of Linear Transformations in Inner Product Space, Gram-Schmidt Process to get Orthonormal Bases, Projections, and Idempotent Transformations, Dual Space of Inner Product Space, Adjoins of Linear Transforms of Inner Product Spaces, Riesz's Representation Theorem: Minimizing the distance of a vector to the subspace, Application to the determination of a function on a set of data: least squares approximation.

References
1. Roman, S, 2005, Advanced linear algebra, 2nd ed., Grad. Text in Math. 135, Springer-Verlag.
2. Weintraub, S.H., 2011. A Guide to Advanced Linear Algebra (No. 44). MAA.
3. Lax, P.D., 2007, Linear algebra and its applications, 2nd ed., John Wiley & Sons.
4. Curtis, M.L., 2012. Abstract linear algebra. Springer Science & Business Media.
5. Cooperstein, B., 2010. Advanced linear algebra. CRC Press.

MMM 5203 ALGEBRAIC STRUCTURE (3 CU)

PREREQUISITES

Students should be familiar to linear algebra

LEARNING OUTCOMES

After taking this course, students will be able to:

CO 1. Clarifies the various concepts, definitions and properties of groups, subgroups, normal groups, quotient groups, symmetry groups, cyclic groups, and direct product groups.

CO 2. Clarifies various concepts, definitions and properties of group homomorphisms, action groups on a set and Sylow's Theorem.

CO 3. Clarifies various concepts, definitions and properties of ring, subring, ideal, ring quotient, and ring homomorphism.

CO 4. Clarifies various concepts, definitions and properties of special elements in rings as well as properties related to special rings and extension fields.

CO 5. Clarifies concepts related to Zorn's Lemma and the Axiom of Choice in groups and rings.

SYLLABUS

Part 1: Group Theory

Review of the basic ideas of group theory: Background and Motivation. Groups and subgroups, examples and their properties. Cosets and Lagrange's Theorem. Finite groups: Symmetry groups, and permutation groups. Abelian group, Quotient Group, Direct product groups, Factor groups from normal subgrups and cyclical groups. Group Homomorphism, Kernel and Image. The Fundamental Homomorphism Theorem. Isomorphism, Inner Automorphism and Outer Automorphism. The first, second, third isomorphism theorems on groups. Group action on a set, orbit, stabilizer. Applications in the conjugate class, centralizer, normalizer. Sylow's theorem and its applications.

Part 2: Ring Theory

A review of the basic ideas of ring theory: Background and Motivation. Rings, subrings and ideals, examples and their properties. Ideal and Quotient Ring. Direct product. Ring polynomial and its properties. Special elements: zero divisor, unit element, prime element, and irreducible element. Prime Ideal and Maximum Ideal. Some special rings: integral Domain, field, Principle Ideal Domain, Euclidean Domain, and Unique Factorization Domain. Multiplicative Closed and localization. Lemma Zorn, The Axiom of Choice and its application. Ring Homomorphism, Kernel and Image. The Fundamental Homomorphism Theorem on Rings. The first, second, third isomorphism theorems on rings. Extension Field, characteristics of a field, algebraic extension

REFERENCES

1. Dummit, D.S, Foote, R.M, 2004, Abstract Algebra, Third Edition, John Wiley & Son, Inc.
2. Grillet, P.A, 1999, Algebra, John Wiley & Son, Inc.
3. Fraleigh, J. B., 2014, A First Course in Abstract Algebra, 7^th, Ed., Pearson Education Limited, Edinburgh Gate, Harlow.
4. Hungerford, T.W, Algebra, 1974, (Graduate Texts in Mathematics, 73) 8th Edition, Springer Verlag.

5. Malik, D.S, Mordeson, J.N, Sen, M.K, 1997, Fundamentals of Abstract Algebra, The McGraw-Hill Companies, Inc.
6. Nicholson, W. K., 2012, Introduction to Abstract Algebra, 4^th, Ed., John-Wiley \& Sons, Inc., Hoboken, New Jersey.
7. Rotman, J.J. 2003, Advanced Modern Algebra Prentice Hall; 1st edition (2002); 2nd printing (2003).
8. Smith, J. D. W., 2016, Introduction to Abstract Algebra, 2^nd, Ed., Taylor & Francis Group, Boca Raton, Florida

MMM 5215 GRAPH THEORY AND COMBINATORICS (3 CU)

PREREQUISITES

Students should have basic knowledge on sets, logics and the main principles in discrete mathematics (counting principle, mathematical induction, pigeonhole principle, and inclusion exclusion principle)

LEARNING OUTCOMES

On successful completion of this course, students should be able to:

CO 1. prove some properties of graph

CO 2. Prove some properties of finite field, finite geometry and latin square

CO 3. solve problems related to graphs and combinatorics

CO 4. make a development or a generalization or combine properties related to graph and combinatorics

SYLLABUS

The study material for graph theory and combinatorics can be divided into 2 parts:

A. Graph Theory

Definition and example of graph, degree, adjacency, incidence, handshaking lemma, subgraph, induced subgraphs, graph isomorphism, regular graph, bipartite graph, special graphs, operation of graphs, graph connectivity, tree, planarity, coloring, matching.

B. Combinatorics

Finite field, finite geometry, projective geometry, Latin square, MOLS, BIBD, algorithm, complexity of algorithm

REFERENCES

1. Dougherty, S.T., 2020, Combinatorics and Finite Geometry, Springer International Publishing

2. Robin J. Wilson, 1998, Introduction to Graph Theory, Fourth Edition, Addison Wesley Longman

3. Bose, R.C., Manvel, B., 1983, Introduction to Combinatorial Theory, Colorado State University, John Wiley and Sons

4. Van Lint, J.H., Wilson, R.M., 1992, A Course in Combinatorics, Cambridge university Press
5. Reinhard Diestel, 2005, Graph Theory, Springer Verlag Heidelberg New York
6. Rosen, K.H., 2011, Discrete Mathematics and Its Applications, Seventh Edition, Mc-Graw Hill Education

MMM 5216 MATRIX ANALYSIS (3 CU)

PREREQUISITES

Students should be proficient in linear algebra.

LEARNING OUTCOMES

On successful completion of this course, students should be able to:

CO 1 explain various advanced concepts and techniques in matrix theory

CO 2 utilize matrices as a tool to solve problems mathematics;

CO 3 Apply basic matrix techniques in various fields such as mathematics, statistics, physics, computer science, and engineering, etc.

SYLLABUS

a. Partitioned Matrices: Elementary Operations of Partitioned Matrices, The Determinant and Inverse of Partitioned Matrices, The Rank of Product and Sum, The Eigenvalues of *AB*
b. Matrix Functions
c. Matrix Norms
d. Matrix Decompositions: Schur Decomposition, Spectral Decomposition, Singular Value Decomposition, Polar Decomposition, Jordan Canonical Forms.
e. Special Types of Matrices: Idempotent matrices, nilpotent matrices, involutary matrices, projection matrices, tridiagonal matrices, circulant matrices, Vandermonde matrices, Hadamard matrices, permutation matrices, doubly stochastic matrices, and nonnegative matrices.,

REFERENCES

1. Zhang, F, 2011, *Matrix Theory*, Second Edition, Springer, Linear Park, Davie, Florida, USA.
2. Zhang, X, 2017, *Matrix Analysis and Applications*, Cambridge University Press.
3. Nicholson, W.K., 2019, *Linear Algebra with Applications*, Base Textbook, Version 2019 –Revision A.
4. Gentle, J,E, 2007, Matrix Algebra : Theory, Computations, and Applications in Statistics, Springer.
5. Goldberg, J.L, 1992, *Matrix Theory with Applications*, McGraw-Hill, Inc.
6. Laub, A.J, 2005, Matrix Analysis for Scientists and Engineers, SIAM.

MMM 5217 SEMIGROUPS AND SEMIRINGS (3 CU)

PREREQUISITES

Before taking this course, students must master the basics of mathematical logic, set theory, and the basics of group theory and ring theory.

LEARNING OUTCOMES

Upon successful completion of this course, students are able to:

CO1: formulate and prove in detail the properties of semigroups.

CO2: connect and reconstructs the semigroup concepts in other fields including algebra, analysis and applications

CO3: formulate and prove in detail the properties of semiring

CO4: connect and reconstructs the concept of semiring in other fields of algebra, analysis, and applications.

SYLLABUS

Semigroup, monoid, subsemigroup, ideal, natural order. Green equivalence and semigroup homomorphism. Regular elements, idempotent elements, inverse elements, generalized inverses. Quotient semigroups, regular semigroups, and inverse semigroups. Application semigroup.

Semiring, subsemiring, ideal. Regular elements, inverse elements, slanted regular. Semiring homomorphisms, the fundamental theorem of homomorphisms, special semirings include independent semirings, quotients, Euclid's, semifields, and dioids. Application

REFERENCES

1. Howie, J. M., 1996, *Fundamentals of Semigroup Theory*, Oxford University Press.
2. Golan,.J.S., 1999, *Semirings and their Applications*, Springer-Science+Business Media B.V., Gondran, M., and Minoux, M., 2010, Graph, Dioids, and Semirings: News Models and Algorithms, Springer.
3. Clifford, A.H. and Preston, G.B., 1961, The Algebraic Theory of Semigroups, *American Math. Society*, Rhode Island.
4. Pietrich, M., 1984, *Inverse Semigroups* (Pure and applied mathematics) (Canadian Mathematical Society Series of Monographs and Advan), John Wiley & Sons, Inc.

MMM 5204 MODULE THEORY (3 SKS)

PREREQUISITES

Students should be proficient in vector space and ring.

LEARNING OUTCOMES

After completing this course the students able to:

CO 1 : recognize the fundamental properties of modules and submodules

CO 2 : recognize the concept of module homomorphism

CO 3 : develop the concepts of generator and linear independence in modules

CO 4 : recognize the concept of exact sequence and use it for further analysis

SYLLABUS

Modules and Submodules, Direct sums, Factor modules, Annihilators, torsion modules and torsion free modules. Module homomorphisms**,** Exact sequences**,** Generator, basis and free modules, Projective modules, Modules over Principal Ideal Domain, Free modules and projective modules, Miscellaneous topics related to module theory for enriching student knowledge.

REFERENCES

1. Adkins, W., Weintraub, S.H., 1992, *Algebra an Approach via Module Theory*, Springer-Verlag, Heidelberg.
2. Blyth, T.S, 2018, *Module Theory an Approach to Linear Algebra*, University of St Andrews.
3. Hungerford, T.H., 1974, *Algebra*, Springer-Verlag, New York.
4. Lang, S., 1965, *Algebra*, Addison-Wesley Publishing Company, Massachusetts.
5. MacLane, S., Birkhoff, G., 1979, *Algebra,* Second Edition, Macmillan Publishing Co., New York.
6. Roman, S., 2005, *Advanced Linear Algebra,* Second Edition, Springer, New York.

MMM 5206 ADVANCED TEORI THEORY (3 CU)
PREREQUISITES

Before taking this course, students must master the introduction of ring theory and introduction of module theory.

LEARNING OUTCOMES

Upon successful completion of this course, students are able to:
CO 1. clarify various concepts, definitions and important properties related to regularity in rings, special ideals, special rings and special modules.
CO 2. prove concepts related to regularity in rings, special ideals, special rings and special modules.
CO 3. linking results and theorems in rings and modules between topics covered in lecture.
CO 4. linking theories, methods and techniques that have been learned in lectures to solve some ring and module problems.

SYLLABUS

The concept of regularity in rings, namely regular elements, regular rings;
Idempotent element, nilpotent element, idempotent ideal, nilpotent ideal, nil ideal;
Prime elements, irreducible elements, prime ideals, and semiprime ideals;
Simple ring, simple module and semi simple module;
Noether ring, Artin ring, Noether module, Artin module;
Various advanced topics related to ring theory and module theory to enrich students' insight: group rings, submodules and prime modules, regular submodules, idempotent submodules, single factorization modules, etc.

REFERENCES

1. Blyth, T.S, 2018, *Module Theory An Approach to Linear Algebra*, University of St Andrews.

2. Adkins, W.A. Weintraub, S.H., 1992, *Algebra: An Approach via Module Theory* (Graduate Texts in Mathematics, 136), Springer-Verlag, New York.
3. Lam, T.Y., 1999, *Lectures on Modules and Rings*, Springer Verlag, New York.
4. Huyn, D.V., Lopez-Permouth, S.R., 2010, *Advances in Ring Theory*, Birkhaeuser, Basel.
5. Lam, T.Y., 1991, *A First Course in Noncommutative Rings*, Springer Verlag, New York.
6. Wisbauer, R., 1991, *Foundation of Module and Ring Theory*, Gordon and Breach, Philadelphia.

MMM 5207 MATRICES OVER RING (3 CU)
PREREQUISITES

Before taking this course, students must master the elementary linear algebra and introduction of ring theory.

LEARNING OUTCOMES

Upon successful completion of this course, students are able to:
CO1: conclude and identify in detail an ideal of ring Mn×n(R) and prove their properties.
CO2: conclude and identify in detail the generalization process of the rank of matrices and prove their properties.
CO3: conclude, identify, and explain the solution of a system of linear equations over a ring, and prove the properties regarding the necessary and sufficient for a system of linear equations to have a solution (as generalization of linear equations over over field).
CO 4: conclude and identify in detail the generalization process of Cayley-Hamilton Theorem and prove their properties
CO 5: conclude and identify in detail the zero divisor in ring Mn×n(R) and prove the properties regarding the relation between zero divisor in ring R and zero divisor in ring Mn×n(R)
CO 6: conclude and identify in detail the eigen values and eigen vector of matrices over rings (as generalization of matrices over field) and prove the properties regarding the relation between eigen values and eigen vector and diagonalization of matrices over rings (as generalization of matrices over field).

SYLLABUS

Matrices with entries from a commutative ring R (Mn×n(R)). Ideal of ring Mn×n(R). The rank of matrix over a commutative ring. Linear system over rings. Primeness of ideal in R and primeness of ideal in Mn×n(R). The Cayley-Hamilton Theorem of Matrices over Rings. The Zero Divisor in ring Mn×n(R). The eigen values and eigen vector of matrices over rings. Diagonalization of Matrices over Rings.

REFERENCES

1. Brown, W. C., 1984, Matrices Over Commutative Rings, Marcel Dekker, Inc.
2. Laksov, D, 2013, Diagonalization of Matrices Over Rings, Journal of Algebra.

3. Zabavsky B., 2005, Diagonalizability theorems for matrices over rings with finite stable range, Algebra and Discrete Mathematics.
4. Ara P., Goodearl K.R, O'meara K.C., and Pardo E., 1997, Diagonaliazation of matrices over regular rings, Linear Algebra and its Applications, Vol.265, pp-147-163.

MMM 5210 GENERALIZED INVERS MATRICES (3CU)
PREREQUISITES

Students have an examination card where the course is stated on.

LEARNING OUTCOMES

After completing this course the students should have:

CO 1 explain existence and construction of generalized inverses

CO 2 apply generalized inverses to solve linear systems and characterize generalized inverses

CO 3 explain the spectral properties (i.e., properties relating to eigenvalues and eigenvectors) of generalized inverses

CO 4 apply generalized inverses to solve linear equations and matrices in partitioned form.

SYLLABUS

a. Existence and Construction of Generalized Inverses
b. Linear Systems and Characterization of Generalized Inverses
c. Spectral Generalized Inverses
d. Generalized Inverses of Partitioned Matrices
e. Computational Aspects of Generalized Inverses
f. Miscellaneous Applications

REFERENCES

1. Adi Ben-Israel and Thomas N.E. Greville, 2003, *Generalized Inverses Theory and Applications*, Springer.
2. Boullion, T. L. and Odell, P. L., 1971, *Generalized Inverse Matrices*, John Wiley & Sons, New York.
3. Rao, C. R. And Mitra, S. K., 1971, *Generalized Inverse of Matrices and its Applications*, Wiley, New York.

MMM 5212 FINITE FIELD (3 CU)
PREREQUISITES

Students should be proficient in linear algebra, intro. to ring and group theories.

LEARNING OUTCOMES

After completing this course the students should have:

CO.1. ability to prove fundamental properties of finite field

CO.2. properly ability to construct finite field
CO.3. ability to explain the use of finite field on other areas of study.

SYLLABUS

Field Extension, Algebraic Extension, Splitting Field, Algebraic Closure, Separable Extension, Inseparable Extension, Galois Group, Galois Fundamental Theorem, Finite Field

REFERENCES

1. Fraleigh, J.B., 2003, *A First Course in Abstract Algebra*, 7th Edition, Pearson New International.
2. Dummit, D.S., Foote, R.M., 2002, *Abstract Algebra*, 2nd Edition, John Wiley and Sons.
3. Lidl, R., Niederreiter, H., 2008, *Finite Field*, Cambridge University Press.

MMM 5214 FUZZY LOGIC (3 CU)

PREREQUISITES

Before taking this course, students must have knowledge of conventional logic (binary logic), tautology, basic theory of analysis, and probability theory.

LEARNING OUTCOMES

Upon successful completion of this course, students are able to:
CO1: Prove the fundamental properties of fuzzy sets and fuzzy logic.
CO2: Generalize the classical algebraic system into a fuzzy algebraic system and prove the applicable properties
CO3: Prove the importance of fuzzy inference and being able to apply it to other fields and the real world, especially the design of intelligent systems or humanistic systems.
CO4 : Prove the fuzzy arithmetic properties.

SYLLABUS

Fuzzy sets and related concepts (membership functions, algebraic operations), fuzzy mapping and extension principles, fuzzy numbers and relations. Binary logic, fuzzy logic, and their relationship. Classical and fuzzy propositions. Classical inference and fuzzy inference, fuzzy arithmetic systems, and fuzzy logic applications.

REFERENCES

1. Barnabas Bede, 2012, Mathematics of Fuzzy set and Fuzzy Logic, Springer
2. Klir, G.J., and Bo Yuan, 1995, *Fuzzy Sets and Fuzzy Logic*, Prentice Hall.
3. Setiadji, 2009, Himpunan dan Logika Samar dan Aplikasinya, Graha Ilmu.
4. Chen, G. and Tat Pham, T. , 2001, Introduction to Fuzzy Sets, Fuzzy Logic, and Fuzzy Control Systems, CRC Press LLC. http://sc.uaemex.mx/xose/html/clases/logica/articles/libro_fuzzy_logic.pdf.

5. James J. Buckley, J.J. and Eslami, E., 2002, *An Introduction to Fuzzy Logic and Fuzzy Sets*, Springer https://link.springer.com/book/10.1007%2F978-3-7908-1799-7

MMM 6202 LINEAR SYSTEM OVER RINGS (3 CU)

PREREQUISITES
Students should be proficient in introduction to mathematical system theory over a field and introduction to ring theory.

LEARNING OUTCOMES
After completing this course, students have the ability to:
CO1. Explains the concept of linear system over commutative rings , namely the background to the emergence of linear systems over commutative rings and the definition of linear sytems over commutative rings.
CO2. Explain the concept of reachability and observability of linear system over commutative rings and characterize reachability and observability of linear system over commutative rings.
CO3. Explain the concept of pole assignabiliyy and coefficient assignability of the linear system over the commutative ring and solve the problem of pole assignability and coefficiient assignability of linear system over commutative rings.
CO4. Explain the concept of parametric stabilization and solve the problem of parametric stabilization.

SYLLABUS
A system with a delay as an over ring system. Reachability and observability of linear sytems over commutative rings. Pole assignability and coefficient assignability. Dynamic stabilization. Paramtris stabilization.

REFERENCES
1. Brewer, J. W. , Bunce, J. W. , and Van Vleck, F. S. , Linear systems over commutative rings, *Lecture Notes in Pure and Appl. Math*., vol. 104, Marcel Dekker, New York, USA, 1986.
2. Brown, W.C., 1993, *Matrices over Commutative Rings*, Marcel Dekker, Inc., New York.
3. Brewer J. W., D. Katz, and W. Ullery, Pole assignability in polynomial rings, power series rings, and Prüfer domains, *J. Algebra* 106 (1987), 265–286.
4. Brewer J.W , D. Katz , and W. Ullery , On the pole assignability property over commutative rings, *J. Pure Appl. Algebra* 48 (1987), 1–7.
5. Ching, W. S. and B. F. Wyman, Duality and the regulator problem for linear systems over commutative rings, *J. Comput. Syst. Sci*. 14 (1977), no. 3, 360–368.
6. Hermida-Alonso, J. A. and T. Sánchez-Giralda, On the duality principle for linear dynamical systems over commutative rings, *Linear Algebra Appl*. 135 (1990), 175–180.

7. Kalman R.E., Lectures on controllability and observability, in: E. Evangelisti (ed.), Controllability and Observability, CIME Summer Schools, vol. 46, Springer, Berlin, Heidelberg, 2010.
8. McDonald, B.R., Linear Algebra over Commutative Rings, 2020, Chapman & Hall/CRC Pure and Applied Mathematics.
9. Olsder, G.J., 1994, *Mathematical Systems Theory*, VSSD, The Netherland.
10. Sáez-Schwedt and T. Sánchez-Giralda , Strong feedback cyclization for systems over rings, *Systems Control Lett*. 57 (2008), 71–77.

MMM 6203 THEORY OF CATEGORY AND FUNGTOR (3 CU)

PREREQUISITES

Algebraic structure : ring, module, vector space, group. Lattice. Topology.

LEARNING OUTCOMES

On successful completion of this module, students will be able to:

CO1: identify the basic concept of category and functor;

CO2: demonstrate the knowledge of basic concept of category and functor;

CO3: demonstrate how to prove properties of category and functor;

CO4: apply the basic concepts of category and functor into concrete set or case.

SYLLABUS

Category and subcategory , Special objects and morphisms , Product and coproduct , Kernel and cokernel, Pullback and pushout, Equilizer and coequilizer, Covarian and contravarian functors, Natural transformation, Two categories which are equivalent.

REFERENCES

1. Anderson, F.W., Fuller, K.R., 1992, *Rings and Categories of Modules*, Springer Verlag, New York.
2. Awodey, S., 2006, *Category Theory*, Clarendon Press, Oxford.
3. Schubert, H., 1972, *Categories*, Springer Verlag, Berlin.
4. Spivak, D.I., 2013, Category Theory for the Scientists, MIT Press.
5. Wisbauer, R., 1991, *Foundation of Module and Ring Theory*, Gordon and Breach, Philadelphia.

MMM 6207 CODING THEORY (3 CU)

PREREQUISITES

To participate in this course, a foundation of knowledge in Linear Algebra, Number Theory, Algebraic Structures including groups, rings, and fields is required.

LEARNING OUTCOMES

After completing this course the students should have:

CO 1. ability to prove the fundamental properties in coding theory such as encoding, decoding, field, polynomials rings, finite fields.
CO 2. ability to find a generator matrix and a parity-check matrix of a linear code.
CO 3. ability to encode and decode linear codes (standard array decoding, syndrome decoding) and some special linear codes, such as self- dual codes, and cyclic codes, BCH Codes, Reed Solomon Codes, Goppa Codes.
CO 4. abiliy to do further studies and research in coding theory

SYLLABUS

(Before Midterm Exam) Introduction, foundational theory, and reviewing some properties of coding theory, communication channels, Hamming distance, nearest neighbor decoding, maximum likelihood decoding, distance of a code, and some applications of coding theory. Polynomial Rings, Finite Fields, minimal polynomials. Linear Codes, Hamming weight, linear code basis, Generator matrix and parity check matrix, code equivalence, linear code encoding and decoding, Cosets, nearest neighbor decoding, syndrome decoding. Cyclic Codes, BCH Codes, Reed Solomon Codes, Goppa Codes.

(After Midterm Exam) Reviewing selected topics from journal sources related to Coding Theory.

REFERENCES

1. Ling, S. and Chaoping ,X., 2004, *Coding Theory a First Course*, Cambridge University Press.
2. J ¨urgen Bierbrauer, 2017, *Introduction to Coding Theory*, CRC PressTaylor & Francis Group.
3. Vanstone, S.A., Oorschot, P.C.V., 1989, *An Introduction to Error Correcting Codes with Application*, Kluwer Academic Publishers 2.

MMM 6208 CRYPTOGRAPHY (3 CU)

PREREQUISITES

Algebraic Structure

LEARNING OUTCOMES

After the course the student should be able to :
CO1. demonstrate knowledge and understanding of basic notions in cryptography,
CO2. identify some mathematical problems and the associated mathematical theory that underlies the asymmetric cryptographic applications treated in the course, and to solve problems using this theory,
CO3. demonstrate knowledge and understanding the algorithms that are treated in the course, and account for and prove their complexity,
CO4. implement the simpler of these algorithms using mathematical software, and to analyze their complexity in practice.

SYLLABUS

The course treats basic notions in cryptography and the mathematical problems, with associated mathematical theory, that are the basis for asymmetric cryptographical applications such as RSA (both as cryptosystem and digital signature), DH, El Gamal, ECDH, ECDSA and Miller-Rabin. Different algorithms (to solve these mathematical problems) are studied with a focus on their complexity. Algorithms that are treated include fast powering, Shank's baby-step giant-step, Pohlig-Hellman, Pollard's p-1, QS, index calculus, Pollard's rho och Lenstra's ECM.

REFERENCES

1. Buchmann, J.A., 2001, *Introduction to Cryptography*, Springer-Verlag, New York, Berlin, Heidelberg.
2. Douglas, E., Stinson, R., 2002, *Cryptography Theory and Practice*, 2ndEd, A CRC Press Company, Boca Raton, London, New York, Washington DC.
3. Hoffstein, J., Pipher, J., Silverman, H.J., 2014, *An Introduction to Mathematical Cryptography* (Undergraduate Text in Mathematics), Springer Science-Business Media, New York.
4. Katz, J., Lindell, Y., 2015, *Introduction to Modern Cryptography*, 2nd Edition, CRC Press Taylor and Francis Group, U.S.
5. Patterson, W., 1987, *Mathematical Cryptology for computer scientist and Mathematicians*, Rowman & Littlefield, United States of America.
6. Peikert, C., 2016, *A Decade of Lattice Cryptography*, Department of Computer Science and Engineering, University of Michigan.

MMM 6209 ALGEBRAIC GRAPH THEORY (3 CU)

PREREQUISITES

Students should have basic knowledge elementary linear algebra, graph theory and group theory

LEARNING OUTCOMES

On successful completion of this course, students should be able to:

CO 1. prove some properties of algebraic graph

CO 2. give argumentation related to the properties of algebraic graph

CO 3. make a connection between graph theory and algebra

SYLLABUS

This course covers topic in graph theory and the connection with algebra, particularly linear algebra and group theory.

Content in detail: review on graph concept, adjacency matrix and incidence matrix and the properties, circulant graph; Johnson graph; regular graph, line graph, eigen value of graph, eigen value of some particular graphs, Cayley graph, Cayley graph of symmetric group, graph automorphism; transitivity of graphs (vertex transitive, edge transitive, distance transitive, retract; incidence graph, core

REFERENCES

1. Ravindra B. Bapat, 2010, *Graphs and Matrices*, Springer.
2. Chris Godsil and Gordon Royle, 2001, *Algebraic Graph Theory*, Springer.
3. Norman Biggs, 1996, *Algebraic Graph Theory*, Cambridge University Press.
4. Ulrich Knauer, 2011, *Algebraic Graph Theory*, De Gruyter.
5. Lowell W. Beineke, Jay S. Bagga, 2021, *Line Graphs and Line Digraphs*, Springer.
6. D.S. Malik. John M. Mordeson, M. K. Sen, 1996, *Fundamentals of Abstract Algebra*, McGraw-Hill College.
7. Howard Anton and Chris Rorres, 2013, *Elementary Linear Algebra* : Applications Version, 11th Edition, John Wiley and Sons.

MMM 6210 ALGEBRAIC NUMBER THEORY (3 CU)

PREREQUISITES

Students should be familiar to elementary number theory and algebraic structures.

LEARNING OUTCOMES

On successful completion of this course, students should be able to:

CO 1. solve problems related to basic number theory.

CO 2. solves problems related to quadratic field arithmetic Q[√D].

CO 3. solve problems related to quadratic forms and elliptic curves.

CO 4. apply algebraic number theory to other fields such as cryptography and coding

SYLLABUS

The study material for algebraic number theory can be divided into 2 parts:

A. Elementary number theory and quadratic field (before mid-exam)

Divisibility, Congruences, Division Algorithms, Diophantine equations, Jacobi symbols, quadratic residue, Basic Ring Theory (definitions and examples, ideals, homomorphisms, factor rings, prime ideals, operations on ideals, prime ideals and maximal ideals), Quadratic Field (Q[√D]) arithmetic, ideal factorization, ideal norm, fractional ideals, prime ideals, ideal group class, computational ideal group class,

B. Quadratic form, elliptic curve, and application of algebraic number theory

Theory of quadratic form, quadratic form parameters, reduced definite positive form, Elliptic curves (definitions and examples, transformations to the Weierstrass form, elliptic curves over C, R and other fields), Application of algebraic number theory in cryptography and coding theory.

REFERENCES

1. Trifković, M., 2013, Algebraic Theory of Quadratic Numbers, Springer.
2. Koch, H., 2012, *Algebraic Number Theory*, Springer Science & Business Media.

3. Lang, S., 2013, *Algebraic Number Theory*, Springer Science & Business Media.
4. Cohen, H., Axler, S. and Ribet, K.A., 2007, *Number theory*: Volume I: Tools and Diophantine equations, Springer New York.
5. Voight, J., 2021, *Quaternion Algebras*, Springer Nature.

MMM 6211 CAPITA SELECTA ALGEBRA A (Topic in Graph Theory) (3 CU)
PREREQUISITES
Students should have basic knowledge on graph theory and algebraic structure such as group theory and ring theory.

LEARNING OUTCOMES
On successful completion of this course, students should be able to:
CO 1. clarify some concept on the graph labelling and or algebraic graph
CO 2. give argumentation to the related topic
CO 3. make some conjectures on the related topic

Syllabus
This course covers advance particular topic including labelling and algebraic graph theory
References
1. Gallian J.A. , A Dynamic Survey of Graph Labelling: The Electronic Journal of Combinatorics.
2. Ravindra B. Bapat, 2010, Graphs and Matrices, Springer.
3. Chris Godsil and Gordon Royle, 2001, Algebraic Graph Theory, Springer.
4. Norman Biggs, 1996, Algebraic Graph Theory, Cambridge University Press.
5. Ulrich Knauer, 2011, Algebraic Graph Theory, De Gruyter.
6. John B. Fraleigh, 1999; A First Course in Abstract Algebra; Fourth Edition; Addison-Wesley Publishing Company, Inc.
7. D.S. Malik, John M. Mordeson, and M.K. Sen, 1998, Fundamental of Abstract, Fourth Edition, Addison-Wesley Publishing Company, Inc.

MMM 6212 CAPITA SELECTA ALGEBRA B (Topic in Algebraic Geometry) (3 CU)
PREREQUISITES
Before taking this course, students must master the basics of number theory and algebraic structures especially about ring theory

LEARNING OUTCOMES
Upon successful completion of this course, students are able to:
CO.1. explain the concept of Hilbert's basis and prove in detail its properties.
CO.2. explain the concept of a surface and prove in detail its properties.
CO.3. clarify and prove in detail the Groebner properties of the Zariski bases and topology.

CO 4. reconstructs the concept of commutative algebra in geometry

SYLLABUS

Commutative algebra, ring of polynomials, Hilbert bases and theorems, Nullstellensatz Hilbert, Affine and projective variability, morphism and rational mapping between varias, conics, plane curves, and quadratic surfaces, Groebner Basis, Zarizki topology, irreducibility and dimensions, applications in elliptic curve geometry, Bezout's theorem, and Riemann-Roch . theorem

REFERENCES

1. Eisenbund., D., 2004, *Commutative Algebra with a View Toward Algebraic Geometry*, Springer-Science+Business Media Inc., New York.
2. Gortz, U, and Wedhorn, T., 2010, *Algebraic Geometry* I: Scheme with Examples and Exercises, Springer Inc.
3. Lefschetz, S., 2005, *Algebraic Geometry*, Dover Publications, Inc. Mineola, New York.
4. Milne., J.S., 2017, *Algebraic Geometry*, https://www.jmilne.org/math/CourseNotes/AG510.pdf.

MMM 6213 CAPITA SELECTA ALGEBRA C
(TOPIC IN ALGEBRA MAX-PLUS) (3 CU)
PREREQUISITES

Students have taken Introduction to Cryptography course (MMM-4206) and have an examination card where the course is stated on.

LEARNING OUTCOMES

Upon successful completion,

CO 1. Students are able to comprehend the cryptosystem and to construct the ciphermodel of a problem.

CO 2. Students are able to comprehend the cryptanalysis and to apply for some populer ciphers.

CO 3. Students are able to comprehend the Multicryptosystem and to build the cryptosystem of some famous systems.

CO 4. Students are able to apply max plus algebra comprehend some kind public-key systems and to implement to solve some daily problems.

SYLLABUS

Finite field, polynomial ring; computational complexity; cryptosystem, Hash function, public key cryptosystem RSA,SHA, AES, El Gamal, Elliptic curve, Signatures scheme of RSA and El Gamal, randomness RNG, PRNG; Introduction to distributed ledger/block chain, post quantum cryptography, privacy preserving (zero knowledge); max plus algebra, max plus algebra cryptography.

REFERENCES

1. Baccelli, F. Cohen, G. Olsder, G.L and Quadrat, J.P, *Synchronization and Linearity*, Wiley, N.
2. Gaubert,S, Methods and applications of (max,+) linear algebra, STACS 1997, *Lecture Notes in Computer Science 500*, Springer-Verlag, Berlin, (1997), pp. 261-282.
3. Olsder, G.J. and Roos, C., Cramer and Cayley-Hamilton in the max-algebra, *Linear Algebraand its Applications*, 101 (1988), pp. 87-108.

SYLLABUS COURSES IN APPLEID MATHEMATICS LABORATORY (23 Courses)

MMM5301 OPTIMIZATION THEORY (3 CU)
PREREQUISITES
Linear Programming

LEARNING OUTCOMES

After completing these course the students will be able:
CO1. to recognize basic concept in non linear optimization problems such as convex set, convex function and theorems related to optimization problems with convex functions.
CO2. to solve optimization problems analytically such as optimization problem without constraints, optimization problem with equation constraints, and optimization problems with inequality constraints.
CO3. to solve optimization problem numerically.
CO4. to relate between the theory and applications of optimization problem, and to interpret the solutions.
CO5. to recognize about introduction to advance theories in optimization.

SYLLABUS

Topics include Euclidean space, convex sets, convex functions, quadratic forms, real functions, gradient, directional derivative, local and global extrema, unconstrained extrema, constrained extrema with equation by Lagrange multiplier, constrained extrema with inequality by Kuhn-Tucker theory, numerical methods: direct search, gradient method, Newton-Raphson method, numerical method for n-dimensional problem, numerical method for constrained extrema problem, application of optimization theories to simple real problems, introduction to advance theories of optimization such as: convex functions with nonconvex domains, quasiconvex functions, optimization for nondifferentiable functions, multi objective optimization, more numerical methods for optimizations problems, application of optimization theories on linear quadratic optimal control problems.

REFERENCES

1. Boyd, S., Vandenberghe, L., 2004, *Convex Optimization,* Cambridge University Press.

2. Edwin K.P. Chong, dan Stanislaw H. Zak, 1996, *An Introduction to Optimization*, John Wiley & Sons.
3. Mokhtar S Bazaraa, Hanif D. Sherali, C.M.Shetty, 2006, *Nonlinear Programming. Theory and Algorithms* 3rd Edition, John Wiley and Sons.
4. Mital, K.V., 1993, Optimization Methods in Operations Research and Analysis, Wiley Eastern Ltd.
5. Aragon, F.J., Goberna, M.A., Lopez, M.A., Rodriguez, M.M.L, 2019, *Nonlinear Optimization*, Springer Undergraduate Texts in Mathematics and Technology, 1st ed.

MMM5317 MATHEMATICAL MODELLING AND COMPUTATION (3 CU)
PREREQUISITES
Before taking this course, the students must have a good understanding about the concept of the Differential Equations and some basic concept of Probability Theory and Stochastic Process.

LEARNING OUTCOMES
After completing this course, the students should have:
CO 1. Ability to classify the mathematical model due to the problems
CO 2. Ability to create a deterministic model to connect a simple real problem with the concepts on Mathematics and give the solutions of the problem in mathematical point of view
CO 3. Ability to create a probabilistic model to connect a simple real problem with the concepts on Mathematics and give the solutions of the problem in mathematical point of view
CO 4. Ability to interpret the mathematical results of a model to the original problems.

SYLLABUS

Motivation of Mathematical Modeling, basic concept of Mathematical Modeling, some simple mathematical models and their analysis, mathematical modeling based on the system of the differential equations with computations, and mathematical modelling based on the probability theory with computations.

REFERENCES
1. Altiok, T., Melamed B., 2007, *Simulation Modeling and Analysis with ARENA*, Academic Press.
2. Bishop, 2006, Pattern Recognition and Machine Learning, Springer.
3. Haberman, R., 2003, Mathematical Models: Mechanical Vibrations, Population Dynamics, and Traffic Flow, Prentice Hall Inc, Englewood Cliffs, New Jersey
4. Kulkarni, V. G., 2011, Introduction to modeling and analysis of stochastic systems, Springer New York.
5. Shier, D. R., Wallenius, K. T., 1999, *Applied Mathematical Modeling A Multidisciplinary Approach*, Chapman and Hall/CRC.

MMM5303 DIFFERENTIAL EQUATION (3 CU)

PREREQUISITES

Students have knowledge of the concept of ordinary differential equations

LEARNING OUTCOMES

After completing this course, the students have the ability to:

CO 1. prove the fundamental theorem of a differential equation.

CO 2. justify and evaluate the existence and uniqueness of solutions of initial value problems for ordinary differential and systems of differential equations.

CO 3. justify the characteristic of autonomous systems' equilibrium/critical points.

CO 4. justify and evaluate traveling wave solutions.

CO 5. justify and evaluate the stability of the equilibrium/critical points of partial differential equations.

SYLLABUS

Fundamental theorems of differential equations, existence and uniqueness of solution of ordinary differential equations and systems of differential equations with initial conditions, extension of solution, approximation solutions, stability and characteristics of equilibrium/critical points, linearization method, traveling wave solutions, and stability of the equilibrium/critical points of partial differential equations.

REFERENCES

1. Hurewicz W., 1958, *Lectures on Ordinary Differential Equations*, Massachusetts Institute of Technology, USA.
2. Ross S.L., 1984, *Differential Equations*, John Wiley and Sons, New York.
3. Perko L., 2000, *Differential Equations and Dynamical Systems,* 3rd Edition, Springer-Verlag, New York.
4. Logan J. D., 2008*, An Introduction to Nonlinear Partial Differential Equations,* 2nd Edition, John Wiley and Sons, New Jersey.
5. Drazin. P. G. and Johnson, R S, 1989, *Soliton: an Introduction*, Cambridge University Press, New York.

MMM5307 BOUNDARY VALUE PROBLEM (3 sks)

PREREQUISITES

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LEARNING OUTCOMES

After completing this course the students should have:

CO 1 model the vibrating the string and the circular membrane and solve the models

CO 2 Solve initial value problems by the Integral Transform

CO 3 Solve initial boundary value problem by Fourier-Legendre series

CO 4 Solve initial boundary value problem by Green function

CO 5 Understand conservation law

SYLLABUS

Review of second order linear partial differential equation : classification and reduction in canonical form of the second order linear partial differential equation. The solution of Cauchy problem for Hyperbolic equation in canonical form. Exponential Fourier series, Fourier integral, Legendre-Fourier series and their applications. Wave equation: vibrations on a thin rectangular membrane, vibrations of a Circular Membrane. Heat equation: Uniqueness solution, Gauss Kernel method, Temperature in steady condition in rectangular. in circular plate, in spherical, Laplace equation: harmonic function. Green function in Laplace equation, Helmholtz Operator, wave equation, heat equation. conduction of heat in a rod. Nonlinear conservation law: discontinue solution, Traffic model, Cole-Hoft transformation.

REFERENCES

1. Churchill, R. V., 1961, *Fourier Series and Boundary Value Problems,* MV Graw Hill Book Company, New York.
2. Hanna. J. R. and Rowland J. H., 1990, *Fourier Series and Integrals of Boundary Value Problems*, 2nd Edition, Dover Publication, Inc., New York.
3. Power, D. L., 2010, *Boundary Value Problems and Partial Differential Equations*, Elsevier Inc., San Diego, California.
4. Humi, K. M. and Miller W. B., 1992, *Boundary Value Problems and Partial Differential Equations*, PWS-KENT Publishing Company, Boston.
5. DuChateau P. and Zachmann D. W., 1986, *Partial Differential Equations*, McGraw-Hill, New York.
6. Miller F. H., 1960, *Partial Differential Equations,* John Wiley and Sons, Inc., New York.

MMM5309 CONTROL THEORY (3 sks)

PREREQUISITES

Students should be proficient in solving differential equations and linear algebra

LEARNING OUTCOMES

After completing this course, the students should have:

CO 1. ability to state the principle of open-loop and closed-loop systems;

CO 2. ability to design feedback control;

CO 3. ability to solve linear quadratic optimal control;

CO 4. ability to apply control theory for simple problems and to interpret their solutions.

SYLLABUS

The problem of open loop and closed loop control, control system models. Feedback control and pole placement. Observers. Separation principle. Open-loop quadratic linear optimal control. Lyapunov equation. Quadratic linear regulator closed loop problem. Riccati differential equations. Steady state quadratic linear regulator. Riccati algebraic equations. Solution of Riccati algebraic equations with stable eigenvectors. Application of control theory to simple problems. Introduction to advanced control theory: such as Model Predictive Control, Predictive adaptive control, robust control.

REFERENCES

1. Lewis F.L., 1992, *Applied Optimal Control*, Prentice Hall International.
2. Geert Jan Olsder, 1994, *Mathematical Systems Theory,* 1'st Edition, Delft University of Technology.
3. Katsuhiko Ogata, 1990, *Modern Control Engineering,* 2nd ed. Englewood Cliffs, N.J,: Prentice Hall, Inc.
4. Trentelman, dkk., 2001, Control Theory for Linear Systems, Springer.
5. Nise, N.S., 2015, *Control Systems Engineering,* 7th Edition, Wiley.
6. Dorf, R.C. dan Bishop, R.H., 2011, *Modern Control Systems,* 12th Edition, Pearson.
7. Astrom, K.J., dan Murray, R.M., 2008, *Feedback Systems: an introduction for scientists and engineers,* Princetown University Press.

MMM5310 OPERATIONS RESEARCH (3 CU)

PREREQUISITES

Students should be proficient analysis and algebra

LEARNING OUTCOMES

After completing the course, the student will have:

CO1. ability to formulate optimization problem based on mathematical programming model.

CO2. ability to analyze and solve the mathematics programming model, analytically or numerically.

CO3. ability to interpretate the mathematics programming and to communicate the results to intended users/audiences, both in oral and written language.

SYLLABUS

Convex Optimization for Linear Programming: simplex and non-simplex methods (Karmarkar's method), Integer Programming: Modelling and Methods for solution: Branch and Bound method, Branch and Cut method, integer programming, dynamic programming, genetic algorithm. Inventory Models: Deterministic and Probabilistic Inventory Model. Queueing Theory: Birth and death process.

REFERENCES

1. Poler, R., et.al., 2014, "*Operations Research Problems: Statements and Solutions*", Springer.
2. Boyd, S., and Vandenberghe, L., 2004, "*Convex Optimization*", Cambridge University Press, United Kingdom.
3. Dantzig, G.B dan Thapa, M.N., 1997, "*Operations Research: Applications and Algorithms*", Springer-Verlag, New York.
4. Melanie, M., 1999, An Introduction to Genetic Algorithm, MIT Press.
5. Papadimitriou, C.H., and Steiglitz, K., 1998, "*Combinatorial Optimization*" Dover Publications, United States.

6. Ross, S. M., 1996, "*Stochastics Processes*", Second Edition, John Wiley and Sons, Inc., United States.
7. Sivanandam, S.N. dan Deepa, S.N, 2008, "*Introduction to Genetic Algorithm*", Springer. United States.
8. Winston,W.L., 2004, "Operation Research Applications and Algorithms", Duxbury Press.

MMM5311 APPLIED NUMERICAL METHODS (3 CU)

PREREQUISITES
Before taking this course, it is better if students have understood very wellabout finite difference methods.

LEARNING OUTCOMES
After taking this course, students are expected to be able to choose the right finite difference method to solve
CO 1. elliptic type boundary problems, and assess their accuracy.
CO 2. parabolic type initial and boundary problems, and assess their accuracy.
CO 3. hyperbolic type initial and boundary problems, and assess their accuracy.

SYLLABUS
Introduction, finite difference method. Elliptic Differential Equations: Poisson Equation with Dirichlet and Non-Dirichlet boundary conditions in the rectangular (regular) and irregular domains, accuracy, application. Parabolic Differential Equations: Heat Equations with Dirichlet boundary conditions, Heat Equations with heat sources and decay with Non-Dirichlet boundary conditions, absolute stability, application. Hyperbolic Differential Equations: Advection Equation, Upwind Differencing method and Mac-Cormack method, Convection-Diffusion Equation, absolute stability, application.

REFERENCES
1. Bradie, B., 2006*, A Friendly Introduction to Numerical Analysis*, Pearson Education, Inc., New Jersey.
2. Strikwerda, J. C., 2004, Finite Difference Schemes and Partial Differential Equations, Second Edition, SIAM, Philadelphia.

MMM5312 DISCRETE SYSTEM THEORY (3 CU)

PREREQUISITES
Students should be proficient in differential equation linear algebra

LEARNING OUTCOMES
After completing these course the students will be able:
CO1. to develop model of discrete control problems into basic standard state space form.
CO2. to solve linear systems

CO3. to recognize basic system properties such as stability, controllability and observability and to characterize the properties for discrete systems.
CO4. To design feedback control for discrete systems.
CO5. To design observer for discrete systems, and understand separation principle of feedback control and observer.
CO6. To design linear quadratic optimal control for discrete systems.
CO7. to relate between the theory and applications of simple control system problems, and to interpret the solutions.

SYLLABUS

Topics include modeling aspect and state space form of discrete systems, Z-transform, solution of linear difference equation system, system properties: stability, controllability and observability odf discrete systems, feedback, observer, separation principle of feedback and observer, linear quadratic optimal control for discrete systems, steady state. Application to simple real problems.

References:

1. Katsuhiko Ogata, 1995, *Discrete-Time Control System,* 2'nd Edition, Prentice Hall International Edition.
2. Geert Jan Olsder, 1994, *Mathematical Systems Theory,* 1'st Edition, Delft University of Technology.
3. Kwakernaak, H., dan Sivan, R., 1972, *Linear Optimal Control Systems*, Wiley, Interscience Division of John Wiley and Sons.
4. Rabbath, C.A, Lechevin, N., 2014, 2014th Edition, Springer.

MMM5313 BIOMATHEMATICS (3 sks)

PREREQUISITES

Students should be proficient in differential equation linear algebra

LEARNING OUTCOMES

After completing this course, the students should be able to
CO 1. create models of more complex epidemic problems.
CO 2. solve epidemic problems by investigating the stability of equilibrium points.

SYLLABUS

Introduction: the simplest SIR model. Review: Stability of Equilibrium Points and Linearization method. Direct Methods: Lyapunov Function, La SalleTheorem. First Integral. Basic Reproduction Number. Global Stability. More general SIR model. The SIS and SEIR model. Global stability of reaction-diffusion and its application to epidemic problems.

REFERENCES

1. Braurer F. and Castillo-Chavez C., 2012, *Mathematical Mode;s in Population Biology and Epidemiology,* Second Edition, Springer Science+Business Media, LLC, New York.

2. Perko L., 1991, Differential Equations and Dynamical Systems, Springer-Verlag, New York.
3. Vidyasagar, M., 2002, *Nonlinear Systems Analysis*, SIAM, Philadelphia.
4. Luenberger, D. G., 1979, Introduction to Dynamic Systems: Theory, Models, & Applications, John Wiley & Sons, New York.
5. Castillo-Chavez C., Feng Z., and Huang W., 2002, On the Computation of *R*0 and Its Role on Global Stability, *Mathematical Approaches for Emerging and Reemerging Infections Diseases: Models, Methods and Theory,* Volume I, Springer-Verlag, New York.
6. Korobeinikov, A., and Maini, P. K., 2004, A Lyapunov Function and Global Properties for SIR and SEIR Epidemiological Models with Non-Linear Incidence, *Mathematical Biosciences and Engineering,* Volume I, Number1, June 2004.
7. Hattaf, K. and Yous N., 2013, Global Stability for Reaction-Diffusion Equations in Biology*, Computer and Mathematics with Applications,* 66, pp.1488-1497.
8. Wang N., Zhang L., and Teng Z., 2021, Dynamics in a reaction-diffusion epidemic model via environmental driven infection in heterogeneous space, *Journal of Biological Dynamics,* DOI 10.1080/17513758.2021.1900428
9. Other journals, adjusted as needed.

MMM5314 NONLINEAR DIFFERENTIAL EQUATIONS (3 sks)

PREREQUISITES

Before taking this course, the students must have a good understanding about the concept of the Differential Equations and Elementary Linear Algebra.

LEARNING OUTCOMES

After completing this course, the students should have:

CO 1. Ability to use linear analysis methods for understanding the behaviour of the solution near an equilibrium point.

CO 2. Ability to use some methods to determine the global stability of the equilibrium point.

CO 3. Ability to interpret the solutions of the dynamical system in geometrical point of view.

CO 4. Ability to apply the methods for some related problems.

SYLLABUS

Basic concepts on dynamical systems**,** equilibrium solution and the stability, first Integral and Lyapunov Function, periodic dolution and invariant manifold**,** Poincare Maps.

REFERENCES

1. Wiggins, S., Introduction to Applied Nonlinear Dynamical Systems and Chaos, Springer-Verlag New York, Inc, 1990.
2. Verhulst, F., *Nonlinear Differential Equations and Dynamical Systems*, Springer-Verlag Berlin Heidelberg, 1996.

MMM6301 OPTIMIZATION BY VECTOR SPACE METHODS (3 sks)

PREREQUISITES

Before taking this course, it is better if students have understood very well about Functional Analysis.

LEARNING OUTCOMES

After taking this course, students are expected to be able to:
CO 1. solve some real problems related to minimum norm problems inHilbert Spaces.
CO 2. solve some real problems related to minimum norm problems in Banach Spaces.
CO 3. solve some real problems related to optimization problems of functional.

SYLLABUS

Introduction. Minimum Norm Problem in Hilbert Spaces: Projection Theorem,Primal and Dual Problem, Modified Projection Theorem, Application. Minimum Norm Problem in BanachSpaces: Hanh Banach Theorem, Extension of Hanh Banach Theorem. Application. Optimization of Functional, Problem with constraints, Lagrange Multiplier, Application.

REFERENCES

Luenberger D. G., 1997, *Optimization by Vector Space Methods 1st*, John Wiley & Sons, Inc., New York.

MMM 6320 GAME THEORY (3 CU)

PREREQUISITES

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LEARNING OUTCOMES

After completing these course the students will be able:
CO1. To solve noncooperative game with two players.
CO2. to solve cooperative game with two players.
CO3. to solve cooperative game with n players.
CO 4. to solve linear quadratic dynamic game cooperative with two players
CO5. To relate between the theory and applications of optimization problem, and to interpret the solutions.

Syllabus:

Topics include noncooperative game 2 players, domination, mixed strategy, cooperative game two players, TU games and NTU games, feasible area of cooperative TU game, feasible area of cooperative NTU games, Pareto solution of cooperative TU games, Pareto solution of cooperative NTU games, cooperative games n players, coalitional form, Shapley value, nucleolus, introduction to optimal control, linear quadratic dynamic game two players cooperative, application of game to real problems, introduction to advance theory in game.

REFERENCES

1. Thomas, L..C., 1984, Games, *Theory and Applications*, Ellis Horwood Limited.
2. Ferguson, T.S., 2020, *A Course in Game Theory*, WSPC.
3. Narahari, Y., 2020, *Game Theory And Mechanism Design*, World Scientific.
4. Engwerda, Jacob, 2005, *LQ Dynamic Optimization and Differential Games*, John Wiley & Sons.

MMM 6303 BIFURCATION THEORY (3 CU)

PREREQUISITES
Before taking this course, the students must have a good understanding about the concept of the Differential Equations and Elementary Linear Algebra.

LEARNING OUTCOMES
After completing this course, the students should have:

CO 1. Ability to use linear analysis methods for understanding the behaviour of the solution near an equilibrium point due to the change of the parameter values.

CO 2. Ability to determine the concepts of topological equivalence in Dynamical System.

CO 3. Ability to determine the region of stability of the invariant structures of the dynamical system, such as the equilibrium point and the periodic solutions.
CO 4. Ability to use the concept of topological equivalence to determine the type of the branch point that represents the change of the dynamics of the system.

SYLLABUS
Basic concept on Dynamical Systems, Topological Equivalence, Bifurcation, Structural Stability, One parameter bifurcation of the system for continuous time. One parameter bifurcation of the system for discrete time.

REFERENCES
1. Kuznetsov, Y., *Elements of Applied Bifurcation Theory -2nd ed*, Applied Mathematical Sciences 112, Springer-Verlag New York, Inc, 1998.
2. Verhulst, F., *Nonlinear Differential Equations and Dynamical Systems*, Springer-Verlag Berlin Heidelberg, 1996.

MMM 6305 MATHEMATICAL SYSTEM THEORY (3 CU)

PREREQUISITES
Students should be have good knowledge in Linear Algebra and Introduction to System Theory.

LEARNING OUTCOMES
After completing this course, the students have ability to:
CO 1. formulate the model from a real problem to time varying state space
CO 2. evaluate the solution of linear time varying and the linear time invariant systems

CO 3. analyze the properties of linear time varying systems include of stability, controllability and observability
CO 4. synthesize the system in the form of minimal realization.

SYLLABUS
Mathematical systems. Linearization of the nonlinear systems. Solution of the linear time varying and linear time invarian systems. Impulse respons. Discretization. System properties: stability, controllability and observability. Minimal realization.

REFERENCES

1. Chi-Tsong Chen, 1984, "*Linear Systems Theory and Design*", Holt Rinehart & Winston.
2. Olsder, G.J., 2006, "*Mathematical Systems Theory*", VSSD, The Netherlands.

MMM 6306 FUZZY MULTI-OBJECTIVE LINEAR PROGRAMMING (3 CU)

PREREQUISITES

Students have taken the course of linear programming.

LEARNING OUTCOMES
After completing this course the students should have:
CO1 ability to solve fuzzy linear programming
CO2 ability to solve multi-objective linear programming with fuzzy approach.
CO3 ability to solve the fuzzy multi-objective linear programming.
CO4 ability to apply the fuzzy multi-objective linear programming in the real problem.

SYLLABUS
Introduction: fuzzy set, fuzzy number, fuzzy arithmetic, fuzzy rangking, fuzzy decision. The relationship beetween goal programming and fuzzy programming. Multi-objektif linear programming (MOLP): optimal solution, optimal pareto, goal programming, fuzzy goal programming for solving MOLP. Fuzzy linear programming: Decision making under fuzzy environment and fuzzy linear programming. Fuzzy MOLP: MOLP with fuzzy right hand side and fuzzy technology coefficient, Fuzzy Decisive Set Method, deviation degree measures and weighted max–min method, linear membership function. Fuzzy goal programming (FGP): method for solving FGP. Application of Fuzzy MOLP: case study.

REFERENCES

1. Bector, C.R. and Chandra, S., 2005, *Fuzzy Mathematics Programming and Fuzzy Matrix Games*, Springer.
2. Sakawa, M, 1993, *Fuzzy Sets and Interactive Multi-objective Optimization*, Plenum Press, New York.
3. Mohamed, R.H., 1997, The relationship between goal programming and fuzzy programming, *Fuzzy Sets and Systems*, Vol 89, pp. 215-222.
4. Veeramani,C., Duraisamy,C. and Nagoorgani,A., 2011, Solving Fuzzy Multi-Objective Linear Programming Problems with Linear Membership Functions, *Australian Journal of Basic and Applied Sciences*, 5(8), pp.1163-1171.

5. Cheng, H., Huang, W., Zhou, Q., and Cai, J., 2013, Solving fuzzy multi-objective linear programming problems using deviation degree measures and weighted max–min method, *Applied Mathematical Modelling* , Vol 37, pp. 6855–6869, Elsevier.
6. Fu-Liang,T., 2006, Applying Fuzzy Multi-objective Linear Programming to Transportation Planning Decision, *Journal of Information and Optimization Sciences*, Vol 27, No.1, pp.107-126.
7. Tanino, T., Tanaka, T. and Inuiguchi, M., 2003, *Multi-objective Programming and Goal Programming*, Springer, Berlin.
8. Collette, Y and Sarry Patrick, 2004, *Multiobjective Optimization*, Springer.

MMM 6321 HYPERBOLIC DIFFERENTIAL EQUATION SYSTEM (3 CU)

PREREQUISITES

Students have taken the course of partial differential equations.

LEARNING OUTCOMES

After completing this course the students should have :

CO 1 understand the concept of the hyperbolic consevation Laws

CO 2 apply the hyperbolics system in fluid dynamic, elasticity, traffilc flow and shallow water waves

CO 3 understand the concepts : characteristic; shock, rarefaction waves, weak solution and Riemann problem

CO 4 solve the numerical solution of linear and nonlinear hyperbolic syatem

SYLLABUS

The course covers theory and algorithms for the numerical solution of linear and nonlinear hyperbolic PDEs, with applications including fluid dynamics, elasticity, acoustics, electromagnetics, shallow water waves and traffic flow. The main concepts include: characteristics; shock and rarefaction waves; weak solutions; entropy; the Riemann problem; finite volume methods; Godunov's method; TVD methods and high order methods; stability, accuracy and convergence of numerical solutions.

REFERENCES

1. Randall J. LeVeque, 1992, *Numerical Methods for Conservation Laws*, Lectures in Mathematics, ETH Zurich, Birkhauser.
2. Randall J. LeVeque, 2004, *Finite Volume Methods for Hyperbolic Problems*, Cambridge University Press. Constantine.
3. Dafermos, 2010, *Hyperbolic Conservation Laws in Continuum Physics*, 3rd edition, Grundlehren der Mathematischen Wissenschaften, Vol 325, Springer.
4. Whitham, 1927, *Linear and Nonlinear Wave*, John Wiley and Sons.

MMM 6313 MODEL REDUCTION OF BILINEAR SYSTEMS (3 CU)

PREREQUISITES

Students should be have good knowledge in matrix algebra and differential equations.

LEARNING OUTCOMES

After completing this course, the students have ability to:

CO 1. apply the principles of the model order reduction on linear and bilinear systems.

CO 2. apply several techniques of model order reduction on linear and bilinear systems.

CO 3. analyze the least upper bound of the different systems between the original system and reduced order systems.

CO 4. choose order of the reduced order systems based on least upper bounds of different bilinear systems and another properties.

SYLLABUS

Model order reduction on linear systems. Roots Stability Array, Balanced truncation and singular perturbation methods. Solution and properties of bilinear systems. Model order reduction on bilinear systems. Balanced truncation, singular perturbation and Krylov subspace methods. Advanced topics.

REFERENCES

1. Elliot, D., 2009, Bilinear Control Systems: Matrices in Action, Springer.
2. Olsder, G.J., dan Woude, J.W., 2003, *Mathematical Systems Theory*, Delft University Press.
3. Solikhatun, 2016, Robust H∞ controller for bilinear systems by linear matrix inequalities, Doctoral Dissertation, Institut Teknologi Bandung.
4. Saragih, R. dan Dewanti, I., 2012, Model Reduction of Bilinear System using Balanced Singular Perturbation, Computer Applications for Security, Control ans Systems Engineering, *Communication in Computer and Information Science* 339.
5. Zhou, K., and Doyle, J.C., 1997, *Essential of Robust Control*, Prentice Hall, California Institute of Technology.
6. Trentlemen et.al, 2001, *Control Theory for Linear Systems*, Springer.
7. Amato, F., Cosentino, C., Fiorillo, A. and Merola,A., 2009, *Stabilization of Bilinear Systems via Linear State-Feedback Control,* IEEE Transaction on Circuits and Systems-II: Express Briefs via 56 (1).
8. Al-Shamali, S., Crisalle, O.D., and Latchman, H., Sliding Mode Control for A Class of Bilinear Systems, *Proceedings of the 46th IEEE Conference on Decision and Control New Orleans, LA, USA*, Dec. 12-14, 2007.

MMM 6322 OPTIMAL DESIGN LOGISTIC (3 CU)

PREREQUISITES

Analysis I and Advanced Linear Algebra

LEARNING OUTCOMES

After completing the course, the student will have :

CO1. ability to develop mathematics model in healthcare
CO2. ability to analyze and solve the model analytically or numerically
CO3. ability to interprete the mathematical model and to communicate the results to intended users/audiences, both in oral and written language
CO 4. choose order of the reduced order systems based on least upper bounds of different bilinear systems and another properties.

SYLLABUS

Facility location problems: p-median problems, c-median problems, fixed-charged facility locations problem, application in healthcare.

REFERENCES

1. Laporte, G., et.al., 2019, "*Location Science*", Springer Nature, Switzerland AG.
2. Marthello, S., and Toth, P., 1990, *Knapsack Problems: Algorithm and Computer Implementations,* John Wiley and Sons, Inc., United States.
3. Winston,W.L., 2004, "Operation Research Applications and Algorithms", Duxbury Press.

MMM 6314 OPTIMAL RESOURCE ALLOCATION (3 CU)

PREREQUISITES

Analysis I and Advanced Linear Algebra

LEARNING OUTCOMES

After completing the course, the student will have :

CO 1. ability to develop mathematics model to optimal resource allocation based on *knapsack problems*
CO 2. ability to analyze and solve the model analytically or numerically
CO 3. ability to interprete the mathematical model and to communicate the results intended users/audiences, both in oral and written language.

SYLLABUS

Knapsack Problem 0-1, *bounded-knapsack*, *multiple-knapsack*, *generalised assignment problems, bin-packing problems*, application knapsack problem in schedulling and healthcare.

REFERENCES

1. Poler, R., et.al., 2014, "*Operations Research Problems: Statements and Solutions*", Springer.
2. Marthello, S., and Toth, P., 1990, *Knapsack Problems: Algorithm and Computer Implementations,* John Wiley and Sons, Inc., United States.

MMM 6319 CAPITA SELECTA IN APPLIED MATHEMATICS (3 CU)

Prerequisites: Before taking this course, students must have a good understanding of mathematical concepts related to the topic of the course. Topics and syllabus will be informed by the lecturer before the registration period for each semester.

LEARNING OUTCOMES

Upon successful completion, students will have ability to

CO 1. Combine one or more theories for solving problems in applied mathematics

CO 2. Apply new method for solving problems in applied mathematics

CO 3. Do simple research in applied mathematics

SYLLABUS

Content of this course may vary for each year depend on the lecturer's interest.

REFERENCES

Determined according to the topic and will be announced during the study planning period.

MMM 6323 FRACTAL AND ITS APPLICATIONS (3 CU)

PREREQUISITES

Existing competences in metric space.

LEARNING OUTCOMES

Upon successful completion, students will have ability to
CO 1. Construct and analysis the structure of fractal space
CO 2. Apply the iterated function system to the problems related to structure in fractal space
CO 3. Analysis the dimension of a fractal set
CO 4. Construct and analysis Julia sets
CO 5. Apply fractal to other disciplines

SYLLABUS

a. Introduction: motivation and examples, geometrical approach for transformation, Collage map, definition, and example of fractal

b. Haussdorf metric and fractal space: fractal space, metric space, metric on fractal space.

c. Iterated function space: contractive map, attractor and its existence, Collage Theorem

d. Dimension: example, fractal dimension, similarity dimension, box-counting

e. Julia Set: Dynamical system in R, Dynamical system in C, escape time algorithm
f. Applications

REFERENCES

1. Barnsley, M.F., 2012, *Fractals Everywhere: New Edition*, Dover Books on Mathematics.
2. Falconer, K., 2006, Fractal geometry: Mathematical foundations and applications, John Wiley & Sons.

3. Lapidus, M.L. and Frankenhuijsen, M., 2013, *Fractal Geometry, Complex Dimensions and* Zeta Functions Geometry and Spectra of Fractal Strings, Springer.
4. Pesin, Y. and Climenhaga, M., 2009, Lectures on fractal geometry and dynamical systems, Student mathematical library, vol. 52, *American Mathematical Society*.

MMM 6311 CONTROL THEORY OF BILINEAR SYSTEMS (3 CU)

PREREQUISITES

Students should be have good knowledge in linear algebra and differential equations.

LEARNING OUTCOMES

After completing this course, the students have ability to:
CO 1. construct the model from the real problem into state space form of bilinear systems.
CO 2. evaluate the solution of bilinear systems by using Lie algebra and Volterra series.
CO 3. analyze the properties of bilinear systems consist of stability, controllability and observability.
CO 4. design the controller for bilinear systems consist of linear and quadratic state feedback, sliding mode controller and optimal control.

SYLLABUS

Modelling in state space form of bilinear systems by directly and Carlemen bilinearization. Approximation solution of bilinear systems by Lie algebra and Volterra series. Properties of bilinear systems consist of stability, controllability and observability. Observer. Control theory of bilinear systems: linear and quadratic state feedback, sliding mode controller and optimal control. Advanced topics.

REFERENCES

1. Van der Schaft, A. J., 2004., Equivalence of Dynamical Systems by Bisimulation, *IEEE Transactions on Automatic Control*, 49(12), 2160-2172.
2. Milner, R., 1989, *Communication and Concurrency*, Prentice Hall, Englewood Cliffs.Trentleman et. all, 2001, *Control Theory for Linear Systems*, Springer.
3. Basile, G., & Marro, G., 1992, *Controlled and Conditioned Invariants in Linear System Theory*, Prentice Hall, Englewood Cliffs, NJ.
4. Antoulas, A. C., 2005, *Approximation of Large-Scale Dynamical Systems*, Society for Industrial and Applied Mathematics, Philadelphia.

COURSE SYLLABUS IN STATISTICS LABORATORY
(34 COURSES)

MMM 5401 STATISTICAL MATHEMATICS I (3 CU)

PREREQUISITES

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LEARNING OUTCOMES

By the end of this course :

CO 1. Students are able to understand and explain mathematically the probability distribution and characteristic properties

CO 2. Students are able to explain the mathematical formulas that find the value of the moment of a random variable distribution

CO 3. Students are able to apply theory mathematics statistics to estimate the parameter distribution from data.

SYLLABUS

Probability and Conditional Probability, Random Variables: Expected Value and Variation; Independence.

Discrete Distributions: Binomial, Poisson.

Continuous Distributions: Normal, Log Normal, Student-t, Exponential, Gamma, F, etc;

Moment Generating Function. Two Random Variables : Bivariate Discrete and Continuous RV, Conditional Distributions, Independence of RV. Product Moments of Bivariate RV: Covariance, Independence of RV, Variance of the Linear Combination of RV, Correlation and Independence. Conditional Expectations of Bivariate RV : Conditional Expected Values and Conditional Variance. Functions of RV and Their Distribution : Distribution Function Method, Transformation Method for Univariate Case, Transformation Method for Bivariate Case, Convolution Method for Sums of RV, Moment Method for Sums of RV. Methods of parameter Estimation: Moment Method Estimation and Maximum Likelihood Estimation

The level of this lecture is from knowledge until application however the weighting of this lecture is more knowledge.

The level of this lecture is from knowledge until application however the weighting of this lecture is more knowledge.

REFERENCES

1. Bain, L.J. and Engelhardt, (1992), Introduction to Probability and Mathematical Statistics, Duxbury Press.
2. Prasanna Sahoo, 2013. Probability And Mathematical Statistics, University of Louisville, Louisville, USA.
3. Hogg,R.V.,Kean,J.W.,Craig,A.T.(2005).Introduction to Mathematical Statistics.Pearson Prentice Hall.
4. Larsen,R.J.,Marx,M.L.(2006).An Introduction to Mathematical Statistics and Its Applications.Pearson Prentice Hall.

MMM 5402 STATISTICAL MATHEMATICS II (3 CU)

PREREQUISITES

MMM 5401 STATISTICAL MATHEMATICS I

LEARNING OUTCOMES

By the end of this course :

CO1. Have a good understanding in the concept of the sampling distribution, sufficient statistics, ancillary, and completeness.

CO2. Have the ability to estimate parametersd to evaluate the goodness of an estimator.
CO3. Have the ability to do hypothesis testing and apply it to real data.
CO4. Able to develop or apply mathematics and develop new challenges

SYLLABUS

Joint distribution, Likelihood function.
Methods of parameter Estimation: Moment Method Estimation and Maximum Likelihood Estimation.
Statistic and sampling distributions, Sufficient statistics, Exponential family, Point estimation and its evaluation, Hypothesis testing, Application to real data.
The level of this lecture is from knowledge until application however the weighting of this lecture is more knowledge.

REFERENCES

1. Bain, L.J. and Engelhardt, 1992, Introduction to Probability and Mathematical Statistics, Duxbury Press.
2. Larsen, R.J., Marx, M.L, 2006, An Introduction to Mathematical Statistics and Its Applications, Pearson Prentice Hall.
3. Hogg, R.V., Kean, J.W., Craig, A.T, 2005, Introduction to Mathematical Statistics, Pearson Prentice Hall.

MMM 5403 STOCHASTIC PROCESSES (3 CU)

PREREQUISITES

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LEARNING OUTCOMES

On successful completion of this course, students should be able to:

CO1 explain the concept of Markov Chain, Poisson Process, Birth and Death Process, Continuous-time Markov Chain, Brownian Motion; Queueing models

CO2 determine appropriate models for specific processes and use the concepts, theorems, and computational methods to describe the models;

CO3 appraise advanced models/methods to describe certain random process

SYLLABUS

Markov Chain; Classification of states and chains; Limiting distribution of chains; Inference on Markov Chain data and simulations; Poisson Process; Birth and Death Process; Continuous-time Markov Chain; Brownian Motion; Queueing models: Introduction, M/M/1 queueing.

REFERENCES

1. Ross, S.M., 1996, Stochastic Processes, John Wiley & Sons.
2. Stirzaker, D., 2005, Stochastic Processes and Models, Oxford University Press.
3. Ross, S.M., 2010, Introduction to Probability Models, 10th ed., Academic Press.

MMM 5404 MULTIVARIATE ANALYSIS (3 CU)

PREREQUISITES

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LEARNING OUTCOMES

On successful completion of this course, students should be able to:
CO 1 understands Multivariate Random Variables
CO 2 understands the Theory of Estimation dan Hypothesis Testing
CO 3 understands Multivariate techniques
CO 4 apply Multivariate analysis.

SYLLABUS

Multivariate Random Variables, Multivarite distributions, Theory of the Multinormal, Theory of Estimation, Hypothesis testing, Principal components analysis, Factor analysis, Cluster analysis, Discriminant analysis, Corespondence analysis.

REFERENCES

1. Hardle, W. dan Simar,L. , 2007, Applied Multivariate Statistical Analysis, Springer, New York.
2. Johnson, R.A. dan Wichern, D.W., 2007, Applied Multivariate Statistical Analysis, Pearson Education, Inc. USA.
3. Everitt, B. dan Hothorn,T., 2011, An Introduction to Applied Multivariate Analysis with R, Springer, New York.
4. Khattree, R. and Naik, D. N., 2003, *Applied Multivariate Statistics with SAS Software*, John Wiley & Sons, Inc.

MMM 5406 LINEAR MODEL (3 CU)

PREREQUISITES

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LEARNING OUTCOMES

After completing this course the students have ability to :

CO 1. understand aspects of inverse generalized matrices and quadratic forms.

CO 2. estimates the linear rank model is not full.

CO 3. reduces the properties of the estimator.

CO 4. look for the estimated variance component.

SYLLABUS

Generalized Inverse Matrices, Quadratic Forms and Their Distributions, Model Full Rank, Incomplete Rank Model, Two Element Model, Classification Two-Way Cross, Method of Estimating Component Variance of Data No Balanced, Generalized Linear Model (GLM)

PUSTAKA ACUAN

1. Searly, R., 2012, Linear Model, Wiley.
2. Rencher A.C., 2008, Linear Models in Statistics, Wiley.

MMM 5408 BAYESIAN INFERENCE (3 CU)

PREREQUISITES

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LEARNING OUTCOMES

CO 1 understands Bayesian inference

CO 2 understands Bayesian of assessment assumptions

CO 3 understands Random effect model

CO 4 Aply Bayesian inference

SYLLABUS

Nature of Bayesian inference, Bayesian inference for the difference between two mean, Inference of variance ratio, Bayesian of assessment assumptions, inference of robustness, Random effect model, Analysis of cross-classification design. Bayesian multivariate analysis.

REFERENCES

1. Hoff, P. D., 2009, A First Course in Bayesian Statistical Methods, Springer, New York.
2. Samaniego, F.J., 2010, A Comparison of the Bayesian and Frequentist Approaches to Estimation, Springer, New York.
3. Box, G. dan Tiao, G., 1973, Bayesian Inference in Statistical Analysis, Addison-Wesley Publishing Company Inc. Reading, Massachusetts.
4. Ghosh, J.K., Delampady, M. dan Samanta, T. , 2006, An Introduction to Bayesian Analysis, Springer, New York.
5. Subanar, 2006, Inferensi Bayesian, Universitas Terbuka, Jakarta.

MMM 5409 DESIGN OF EXPERIMENT (3 CU)

PREREQUISITES

-

LEARNING OUTCOMES

After completing this course the students have ability to :

CO 1. explain procedures of some experimental design types

CO 2. determine a suitable design for an experiment

CO 3. Apply an experimental design for real cases

CO 4. analyze the experimental data properly

SYLLABUS

Incomplete block designs, Balanced incomplete block designs, Factorial designs at 2 levels, Fractional factorial designs, Twolevel fractional factorial designs, Robust design, Optimal design.

REFERENCES

1. Buyske, S., 2011, Lecture Note: Advanced Design of Experiment.
2. Heinkelmann, K., Kempthorne, O., 2005, Design and Analysis of Experiments, Vol 2 (Advanced Experimental Design), John Wiley & Sons, New Jersey.
3. Box, G.E.P., Hunter, J.S., Hunter, W.G., 2005, Statistics for Experiments Design: Innovation & Discovery, Second edition, John Wiley & Sons, New Jersey.

MMM 5410 ECONOMETRICS (3 CU

PREREQUISITES

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LEARNING OUTCOMES

After completing this course the students have ability to :

CO 1. understand econometric method

CO 2. understand various econometric models and their properties.

CO 3. perform statistical inference on econometric models

CO 4. understand and be able to apply analysis and solve econometric problems.

SYLLABUS

Introduction, multiple linear regression method and its assumptions, non-scalar identity model. Heteroscadasity model, autocorrelation model, SUR (Seemingly Unrelated Regression) model, stochastic predictor model and simultaneous equation system model.

REFERENCES

1. Gujarati, D.N., 2003, Basic Econometrics, 4th ed. New York: McGrawHill International.
2. Greene, W.H., 2000, Econometrics Analysis, 4th ed. New York: Macmillan Publishing Company.
3. Judge, et al., 1982, Introduction to the Theory and Practice of Econometrics, New York: John Wiley & Sons.

MMM 5411 TIME SERIES ANALYSIS (3 CU)

PREREQUISITES

No Prerequisite

LEARNING OUTCOMES

On successful completion of this course,

CO1. Students should understand the statistical concept related to time series analysis

CO2 Students are able to model realistic time series data using the methods learned in class.

CO3 Students can model the data using time series model, with the help of statistical software, such as R, Eviews, or others

SYLLABUS

Topics include basic concepts, such as: Stochastic process, the auto covariance and the auto correlation function (ACF), the partial ACF (PACF), strictly and wide-sense stationary, causality and invertibility; Estimating the mean, ACF and PACF; Some stationary models (White noise, Moving Average/MA, Autoregressive/AR, ARMA), Estimation and forecasting stationary models, Diagnostic check methods, some non stationary model: ARIMA, SARIMA, ARIMAX and ARCH/GARCH, Extended models related to the new research, Computation using R

REFERENCES

1. Rosadi, D., 2014, Analisa Runtun Waktu dengan R, GAMA Press.
2. Brockwell, P.J. dan Davis, R.A., 1996, Introduction to Time Series and Forecasting, Springer Verlag, Berlin.
3. Enders, W., 2004, Applied Econometric Time Series, Wiley.
4. Abraham, B. and Ledolter, J., 1983, Statistical Methods for Forecasting, Wiley.
5. Gourieroux, C., 1997, ARCH Models and Financial Applications, Springer-Verlag.
6. Quantitative Micro Software, LLC, 2001, Eviews 4 User's Guide, Quantitative Micro Software.
7. Verbeek, M., 2000, A Guide to Modern Econometrics, John Wiley.
8. Makridrakis, W., 1999, Metode dan Aplikasi Peramalan, Second Edition, Binarupa Aksara.

MMM 5412 LONGITUDINAL DATA ANALYSIS (3 CU)

PREREQUISITE

No Prerequisite

LEARNING OUTCOME

After completing this course, students will be able to:

CO 1. Apply fractals in other fields.

CO 2. Identify phenomena related to longitudinal data, applications, and the benefits of longitudinal data in various real-world problems.

CO 3. Explore graphs and numerical summaries for longitudinal data.

CO 4. Explain the theory underlying the General Linear Model for longitudinal data and be able to model and interpret the results.

CO 5. Explain the theory underlying the Generalized Linear Model for longitudinal data and be able to model and interpret the results.
CO 6. Explain the differences between marginal models, random effects models, and transitional models, and be able to model and interpret the results of each model.
CO 7. Present and explain an advanced topic on longitudinal data analysis.

SYLLABUS
Longitudinal data and design, exploratory data for longitudinal data, linear models; general linear models; generalized linear models; generalized estimating equation models; marginal model; random effect models; transitional models and advanced topic.

REFERENCES

1. Diggle, P. J., Heagerty, P., Liang, K-Y., Zeger, S. L., 2002, Analysis of Longitudinal Data (Second Edition), Oxford University Press.
2. Danardono, 2015, Analisis Data Longitudinal, UGM Press.

MMM-5414 BIOSTATISTICS (3 CU)
PREREQUISITES
No Prerequisite

LEARNING OUTCOMES
After completing this course, the students should be able to:
CO 1 Choose statistical tests in related to medical research hypotheses.
CO 2 Perform bivariable and multivariable analyses.
CO 3 Interpret the statistics pcomputer program output.

SYLLABUS
The teaching materials consist of descriptive and inferential statistics for several levels of measurement, correlation and linear regression, binary logistic regression, survival analysis. In addition, examples and illustrations performed from medical research data.

REFERENCES

1. Daniel, W.W. 2009. *Biostatistics: A Foundation for Analysis in the Health Sciences. John Wiley & Sons, Inc. United States of America*.
2. Rosner, B., 2006, Fundamentals of Biostatistics, Thomson Brooks/Cole, Singapore.
3. Bland, M., 2000, An Introduction to Medical Statistics, Oxford University Press, Oxford.
4. Agresti, A. 2007. *An Introduction to Categorical Data Analysis*. John Wiley & Sons, New York.
5. Montgomery, D.C., Peck, E.A. & Vining, G.G. 2012. *Introduction to Linear Regression Analysis*, John Wiley & Sons, Inc., New Jersey.
6. Hosmer, D.W. & Lemeshow, S., 1989, Applied Logistic Regression, John Wiley & Sons, New York.

MMM 5415 CATEGORICAL DATA ANALYSIS (3 CU)

PREREQUISITES

No Prerequisite

LEARNING OUTCOMES

After completing this course, the students should be able to:

CO 1 Test hypotheses for categorical data summarized in contingency table.

CO 2 Identify properties of the logistic model and apply it.

CO 3 State or recognize when the use of polytomous logistic regression may be appropriate.

CO 4 State or recognize when the use of ordinal logistic regression may be appropriate.

SYLLABUS

Two-way contingency tables, simple and multiple binary logistic regression, multiple polytomous logistic regression, multiple ordinal logistic regression. In addition, study designs in medical research are also discussed.

REFERENCES

1. Agresti, A., 2007, An Introduction to Categorical Data Analysis, John Wiley & Sons, New York.
2. Kleinbaum, D.G. and Klein, M., 2010, Logistic Regression, ASelf-Learning Text, Springer, New York.
3. Agresti, A., 2002, Categorical Data Analysis, John Wiley & Sons, New York.
4. Hosmer, D.W. and Lemeshow, S., 2000, Applied Logistic Regression, John Wiley & Sons, New York.

MMM 5417 SEMIPARAMETRIC REGRESSION (3 CU)

PREREQUISITES

No Prerequisite

LEARNING OUTCOMES

After completing this course the students have ability to :

CO1.Understanding the differences between parametric, nonparametric, and semiparametric regression models.

CO2. Performing parameter estimation for parametric, nonparametric, and semiparametric regression models.

CO 3. Selecting appropriate smoothing parameters.

CO 4. Conducting simulations and real-world examples.

SYLLABUS

Matrix Algebra, Random Vectors and Random Matrices. Parametric Regression, including Simple Linear Regression, Multiple Regression: Hypothesis Testing and Confidence Intervals, General Linear Model, Parameter Estimation, Properties of Estimators, Best Linear Unbiased Estimator (BLUE), Estimator Variance, Histogram Kernel Density Estimation, Nonparametric Regression including Nadaraya-Watson Estimation, Properties of Nadaraya-Watson Estimator, Bandwidth Selection, Semiparametric Regression including Least Squares Estimation in Parametric Component, Properties of Estimator, Nonparametric Component Estimation, Smoothing Parameter Selection, Simulation and Real-World Examples.

REFERENCES

1. Hardle, W., 1991, Smoothing Techniques with Implementation in S, New York, Springer-Verlag.
2. Rencher, A. C., 2000, Linear Model in Statistics, USA: John Wiley & Son Inc.
3. Hardle, W., Liang H., & Gao, J., 1999, Partially Linear Models, Springer Verlag Company.

MMM 5419 TIME-TO-EVENT DATA ANALYSIS (3 CU)

PREREQUISITES

No Prerequisite

LEARNING OUTCOMES

After completing this course, the students should be able to:

CO 1. Explain the underlying theory of between-event data analysis.

CO 2. Identify between-event data in real-world problems.

CO 3. Conduct hazard function and survival function analysis using both parametric and non-parametric methods, for both complete and incomplete data, and explain their fundamental concepts.

CO 4. Perform Parametric Regression analysis for Accelerated Failure Time (AFT) and Proportional Hazards models and explain their basic concepts.

CO 5. Conduct Cox Regression analysis, estimating with Partial Likelihood.

CO 6. Explain counting processes and multi-status models in between-event data analysis.

CO 7. Explain frailty models in between-event data analysis.

SYLLABUS

Time-event-data (survival data); Probability models for time-to-event data; parametric methods for survival and hazards function: Kaplan-Meier, Nelson-Aalen; Survival regression models; Cox's Regression; counting process approach for time-to-event data. Multistate models; Frailty models.

REFERENCES

1. Lee, E.T., Wang, J.W., 2003, Statistical Methods for Survival Data Analysis, 3rd ed., John Wiley & Sons.
2. Klein, J. P dan Moeschberger, M. L., 2003, Survival Analysis: Techniques for Censored and Truncated Data, 2nd ed., Springer.
3. Lawless, J. F., 2002, Statistical Models and Methods for Lifetime Data, 2nd ed. John Wiley & Sons.

MMM 5421 STRUCTURAL EQUATION MODELLING (3 CU)
PREREQUISITES
No Prerequisite

LEARNING OUTCOMES
After completing this course, the students should be able to:
CO 1 understand and explain mathematically the equation of SEM
CO 3 do computation SEM
CO 3 Apply SEM invarious cases

SYLLABUS
Regression Analysis, Principal Component Analysis, Exploratory Factor Analysis, Confirmatory Factor Analysis, Path Analysis, Structural Equation Modeling without intermediate latent variables (first order), Structural Equation Modeling with intermediate latent variables (second order): Measurement models and structural models, parameter estimation: maximum likelihood. Model fit tests: Chi-Square, Model fit indices: CFI, GFI, AGFI. Minimum error measures, fit indices. Data analysis using Amos software.

REFERENCES
Joseph F.H., Wiliam C. B., Barry J. B., Rolph E., Anderson, dan Ronald L.T., 2006, Multivariate Data Analysis, Fifth edition, Pearson Education International.Inc., New Jersey.

MMM 5425 FORECASTING TIME SERIES DATA (3 CU)
PREREQUISITES
No Prerequisite

LEARNING OUTCOMES
After completing this course, the students should be able to:
CO 1. Understand some basic concept related to Forecasting Time series Data
CO2. Use statistical software to do Forecasting Time series Data
CO3. Solve real case

SYLLABUS
In this course, we will discuss the concepts, techniques, and applications of methods used in forecasting. The material includes: Introduction to Forecasting, Forecasting using

smoothing processes, exponential smoothing, adaptive exponential smoothing. Evaluation of the least error using MAD and RMSE measures. Forecasting techniques such as Exponential Smoothing and Moving Averages, Techniques for data containing trends. Time series regression. Holt and Winter methods for data containing trends and seasonality. Box-Jenkins methods such as Moving Average, Autoregressive Models. ARIMA modeling for time series data containing trends and seasonality. Modeling time series data with non-homogeneous variance ARCH and GARCH. Data analysis includes applications in various fields such as finance, industry, agriculture, weather, etc. Data analysis using Excel, MINITAB, SPSS, and Eviews software.

REFERENCES

1. Brockwell, P.J. dan Davis, R.A., 2002, *Introduction to Time Series and Forecasting*, Springer Verlag, Berlin.
2. Enders, W., 2008, *Applied Econometric Time Series*, 2nd Ed, Wiley.
3. Bruce L. Bowerman, Richard T. O'Connell and Anne B. Koehler, 2005, *Forecasting, Time Series, and Regression*: *an Applied Approach* (4th edition), Duxbury Press.

MMM 5426 MULTILEVEL MODELING (3 CU)

PREREQUISITES

No Prerequisite

LEARNING OUTCOMES

After completing this course, the students should be able to:

CO 1 Determe the appropriate statistical method for the research data structure.

CO 2 Conduct data analysis with multilevel data structures.

CO 3 Interpret the output of statistical software packages.

SYLLABUS

Standard regression analysis with continuous and categorical responses, multilevel modeling of continuous and categorical responses.

REFERENCES

1. Rabe-Hesketh, S. & Skrondal, A. 2012. *Multilevel and Longitudinal Modeling Using Stata*. Stata Press, Texas.
2. Montgomery, D.C., Peck, E.A. & Vining, G.G. 2012. *Introduction to Linear Regression Analysis*, John Wiley & Sons, Inc., New Jersey.
3. Hosmer, D.W. & Lemeshow, S. 2000. *Applied Logistic Regression*. John Wiley & Sons, New York.
4. Bickel, R. 2007. *Multilevel Analysis for Applied Research: It's just Regression!* The Guilford Press, New York.
5. Goldstein, H. 2011. *Multilevel Statistical Models*, 4th Edition. John Wiley and Sons, Ltd., Publication.

MMM 5428 CAPITA SELECTA OF STATISTICS (3 CU)
PREREQUISITES
No Prerequisite

LEARNING OUTCOMES
After completing this course, the students should be able to:
CO 1. Understand new methods in the field of Statistics.
CO 2. Build models, estimate model parameters, and perform statistical inference.
CO 3. Conduct statistical development research.

SYLLABUS:
New methods in the field of statistics, estimating model parameters, and performing statistical inference. Statistical development research.

REFERENCES
1. Wackerly, D. D., Mendenhall, W. dan Scheaffer, R. L., 2002, Mathematical Statistics with Applications, Duxbury Press.
2. Rice, J. A., 1995, Mathematical Statistics and Data Analysis, Duxbury Press.

MMM 5429 DATA MINING (3 CU)
PREREQUISITES
No Prerequisite

LEARNING OUTCOMES
After completing this course, the students should be able to:
CO1 Understand how and when data mining can be used as a problem-solving technique.
CO2 Explain different data mining techniques.
CO3 Be able to select the appropriate data mining technique for a specific problem.
CO4 Use available data mining software to mine prepared datasets.
CO5 Evaluate and interpret data mining results.

SYLLABUS
The teaching materials consist of Preprocessing - Data preprocessing Data cleaning, Data reduction, Data warehousing, Data visualization, Association rule, Decision tree, Clustering, Regression, Classification

REFERENCES
1. Zhao, Y., 2015, R Data Mining: Examples and Case Studies, Elsevier.

2. Han. J., Kamber, M., Jia, P., 2012, Data Mining: Concepts and Techniques, Morgan Kaufmann Publisher.
3. Romero, C., dkk, 2011, Handbook of Education Data Mining, Chapman & Hall/CRC.

MMM 5501 FINANCIAL MATHEMATICS (3 CU)
PREREQUISITES
No Prerequisite

LEARNING OUTCOMES
After completing this course, the students should be able to:
CO 1. Understand the use of mathematics in the theory of interest.
CO 2. Understand the theory of annuities.
CO 3. Integrate CO 1 and CO 2 for the application of mathematical finance.

SYLLABUS
This course is a subject that discusses the application of mathematics in the field of finance. Topics include interest, interest rates, simple interest, compound interest, continuous interest, accumulation value, present value, discount rate. The course also studies payment series or annuities, basic annuities, advanced annuities, perpetuities, amortization, and sinking fund.

REFERENCES
1. Kellison, S. G., 1991, The Theory of Interest, John Wiley & Sons, New York.
2. Yuh-Dauh Lyuu, 2004, Financial Engineering and Computation, Cambridge University Press,United Kingdom.

MMM 5502 ACTUARIAL MATHEMATICS (3 CU)
PREREQUISITES
No Prerequisite

LEARNING OUTCOMES
After completing this course, the students should be able to:
CO 1. Explain the concepts of survival data in actuarial science, the functions used, continuous age interpolation, and its applications in actuarial science.
CO 2. Describe the types of life insurance and their underlying models, including premium calculations.
CO 3. Explain the types of life annuities and their underlying models, along with premium calculations.
CO 4. Describe the types of premium reserves and their calculations.

SYLLABUS

Survival Distribution and Mortality Tables: Probability of age at death, survival function, age at death, discrete age, acceleration of death, mortality tables, fractional age assumption. Life Insurance: Insurance with immediate payment at death, Insurance with payment at the end of the death year, relationship between immediate payment insurance and end-of-year payment insurance. Life Annuities: Continuous Annuities, Discrete Annuities. Premiums: Continuous Premiums, Discrete Premiums, Fractional Premiums. Reserves: Continuous Reserves, Discrete Reserves.

REFERENCES

1. Bowers, N.L., Gerber, H.U., Hickman, J.C., Jones, D.A., Nesbit, C.J, 1997, Actuarial Mathematics, Society of Actuaries.
2. London, D., 1997, Survival Models and their Estimation, I, ACTEX.

MMM 5503 MODELING AND RISK THEORY (3 CU)

PREREQUISITE

No Prerequisite

LEARNING OUTCOMES

After completing this course, the students should be able to:

CO-1 Understand the fundamental concepts of probability and risk's random variables

CO-2 Understand the basic concept and its applications on distributional quantities

CO-3 Master the characteristic of actuarial models and their applications

CO-4 Capable of solving actuarial problems using continuous, discrete and aggregate models

SYLLABUS

The purpose of this course is to develop knowledge of the tools used in basic modeling to assess actuarial risks quantitatively. Emphasis is placed on applying these tools to solve problems encountered in actuarial science. Basic distribution quantities, risk measurements, characteristics of actuarial models, continuous and discrete models, frequency and severity with coverage modifications, aggregate loss models.

REFERENCES

Klugman S.A., Panjer H.H., Wilmot G.E., 2012, Loss Models: From Data to Decisions, 4th edition, Wiley.

MMM 5504 ADVANCE IN ACTUARIAL MATHEMATICS (3 CU)

PREREQUISITES

MMM-5502

LEARNING OUTCOMES

After completing this course, the students should be able to:

CO-1: Students will comprehend basic theory of benefit reserves

CO-2: Students will understand main concepts associated with insurance model including expenses

CO-3: Students will understand key concepts of multi life and multi decrement model.

SYLLABUS

The purpose of this course is to develop knowledge of the fundamental actuarial tools for quantitatively assessing risk. The application of these tools to problems encountered in actuarial science is emphasized. A thorough command of the supporting calculus is assumed.

1. Benefit Reserve
2. Insurance model including expenses
3. Multi life model
4. Multi decrement model

REFERENCES

Bower, et.al., 1999, Actuarial Mathematics, Society of Actuaries, Schaumburg, Illinois.

MMM 5505 THE FORMULATION OF MORTALITY TABLES (3 CU)

PREREQUISITE

No Prerequisite

LEARNING OUTCOMES

After completing this course, the students should be able to:

CO 1. Explain the theories underlying survival models and mortality tables.

CO 2. Utilize models and mortality tables for actuarial field problems.

CO 3. Estimate mortality models from complete or incomplete sample data.

CO 4. Develop models and mortality tables based on raw data obtained from insurance policies or other sources.

CO 5. Explain an advanced topic on mortality models and their development.

SYLLABUS

Survival data; mortality models; mortality table construction for complete and incomplete data using parametric and non-parametric methods. Advanced topics for mortality model construction or other advanced models for specific actuarial problems.

Data survival, Model Survival, Tabel Mortalitas, Estimasi untuk data survival lengkap, Estimasi untuk data survival tidak lengkap, Model data survival parametrik, Model data survival non (semiparametrik), Pembentukan Tabel Mortalita, dan Topik Lanjut.

REFERENCES

1. Danardono, 2014, Pembentukan Tabel Mortalita, Diktat S2 Matematika FMIPA UGM.
2. London, D. , 1997, Survival Models and Their Estimation, Third Edition, Chapter 1-11 and appendix, ACTEX Publication.
3. Klugman, S.A., Panjer, H.H. and Willmot, G.E., 2004, Loss Models: From Data to Decisions, Second Edition, Chapter 1, Section 1.1 only, Chapters 9–11, Chapter 12 (excluding 12.5.4, 12.5.5 and 12.6), and Chapter 13, John Wiley and Sons, Inc.
4. Batten, R. W., 1978, Mortality Table Construction, Chapter 1-7. Prentice-Hall.

MMM 5506 ACTUARIAL STATISTICS METHOD (3 CU)
PREREQUISITES
No Prerequisite

LEARNING OUTCOMES
After completing this course, the students should be able to:
CO 1. Students master the fundamentals of analytical-theoretical thinking to obtain estimators, the statistical properties of estimators, and modeling steps in selected econometric and time series models for actuarial data analysis purposes.
CO 2. Students are familiar with operating Eviews software (or other software) for econometric and time series analysis purposes selected for actuarial data analysis.
CO 3. Students can analyze the output of econometric and time series analysis generated by statistical software for actuarial data analysis purposes.

SYLLABUS
Introduction to regression analysis, simple regression, multiple regression (estimator, properties of the estimator, test for the classical assumptions, statistical inference for the estrimator), Regression with dummy variables, Regression with stochastic independent variables, Serial correlation and heteroscedasticity within the regression model, Generalized Least Square (GLS) Estimator and its properties, Extrapolation and smoothing of time series data using deterministic models, modeling seasonality of time series data, modeling time series data using stationary and stationary model (random walk, AR, MA, ARMA, ARIMA), application of the model using some econometrics software.

REFERENCES
1. Pindyck, R. S. and Rubinfeld,D.L., 1998, Econometric Models and Economic Forecasts, Fourth Edition, MCGraw Hill, Boston, Chapters 3–6, 15–18. 6.
2. Gujarati, D., 2004, Basic Econometrics, 4th Eds., Mc. Graw Hill, New York.
3. Rosadi, D., 2011, Analisa Ekonometrika dan Runtun Waktu Terapan dengan R, Andi Ofset, Yogyakarta.
4. Rosadi, D., 2013, Ekonometrika dan Analisa Runtun Waktu Terapan dengan EViews, Andi Ofset, Yogyakarta.

MMM 5508 HEALTH INSURANCE (3 CU)
PREREQUISITES
No Prerequisite

LEARNING OUTCOMES
After completing this course, the students should be able to:
CO-1: Explain the types of health insurance products with their actuarial models
CO-2: Explain and use the claim frequency model, claim severity and collective risk models in health insurance.
CO-3: Explain and use mortality, morbidity and multi-status models in health insurance.
CO-4: Explain actuarial models that can be used in the collective risk insurance system and the national health insurance system.
CO-5: Develop a health insurance product with its actuarial model based on real and simulated data

SYLLABUS
Health Insurance Products; Model claim frequency and claim severity; Mortality, Morbidity and Multi-status Models; Collective Risk Model; Actuarial models related to National Health Insurance

REFERENCES

1. Pitacco, E., 2014, Health Insurance:Basic Actuarial Models, Springer.
2. Cunningham, R. J., Herzog, T. N and London, R. L. , 2006, Models for Quantifying Risk, 2nd ed., ACTEX Publications, Inc.
3. Cichon, M, Newbrander, W, Yamabana, H., Weber, A., Normand, C., Dror, D. and Preker, A., 1999, Modelling in Health Care Finance, International Labour Organization, Geneva.

MMM 5510 FINANCIAL MODELING (3 CU)
PREREQUISITES
No Prerequisite

LEARNING OUTCOMES
After completing this course, the students should be able to:
CO 1 Creating financial model based on Random Walk , Binomial, Multinomial, Brownian motion and Variance Gamma process.
CO 2 able to valuate European and American option
CO 3 Creating financial model based on simulation approach
CO 4 Creating financial model based on Partial Differential equation

SYLLABUS

Modern Finance based on Random Walk, Analysis of Algorithms, Basic Financial Mathematics, Bond Price Volatility, Term Structure of Interest Rates, Option PricingModels, Continuous-Time Financial Mathematics, Numerical Methods

REFERENCES

1. Shreve, S. E., 2000, Stochastic Calculus for Finance I, Springer Finance, New York.
2. Shreve, S. E., 2000, Stochastic Calculus for Finance II, Springer Finance, New York.
3. Higham, D. J., 2004, An Introduction to Financial Option Valuation, Cambridge University Press, Cambridge.

MMM-5511 RISK MANAGEMENT (3 CU)

PREREQUISITES

No Prerequisite

LEARNING OUTCOMES

After completing this course, the students should be able to:

CO1 Understand the basic concept of risk management

CO2 Understand basic concept from finance for risk modeling

CO3 Understand how to model market risk, credit risk and other types of risk and use it for risk management of several financial instruments

SYLLABUS

Introduction to Risk and Risk Management, basic concept from finance: returns, investment and financial market, VaRParametric: VarRNormal, VaR Non normal , Var Non Parametric, Backtesting and Stress Testing, Application VaR for risk management, Introduction to Credit Risk, Application of Risk management for Indonesian Market, Advanced Topics: Option Pricing VaR, Copula Application for Risk Management, Machine Learning for Risk Management, etc.

REFERENCES

1. Dowd, K., 2002, An introduction to market risk measurement, Wiley.
2. Jorion, P. 2001, Value at Risk, McGraw-Hill, New York.
3. Christoffersen, 2003, Elements of Financial Risk Measurements, Academic Press.
4. Rupert, D., 2004, Statistics and Finance, An Introduction, Springer, New York.
5. Rosadi, D., 2017, Manajemen Resiko Kuantitatif, GAMA Press.

MMM 5512 INVESTMENT MANAGEMENT (3 CU)

PREREQUISITES

No Prerequisite

LEARNING OUTCOMES

After completing this course, the students should be able to:

CO 1. Understanding portfolio mathematics.
CO 2. Understanding portfolio allocation methods.
CO 3. Integrating investment theory and practice and analyzing it.

SYLLABUS

Contents of this lecture consist of :
Introduction to investment and types of return
General random variable for return of the portfolio
Simple methods of portfolio: Mean-variance
Portfolio : Simulation methods
Capital Asset Pricing Model
Multi-objective portfolio model
Resampling Efficienct Frontier
Trading portfolio and analysis of performance
Advanced topics in portfolio theory
Case study and paper
Paper review and paper construction

REFERENCES

1. David G. Luenberger, 1998, Investment Science, Oxford University Press.
2. Higham, D. J., 2004, An Introduction to Financial option Valuation: Mathematics, Stochastics and Computation, Second Edition, Cambridge University Press.
3. Andrew T Adam, 2003, Investment Mathematics, John Wiley and Sons.

MMM 5513 FINANCIAL COMPUTATION (3 CU)

PREREQUISITES

No Prerequisite

LEARNING OUTCOMES

After completing this course, the students should be able to:
CO 1 Using computation on finance
CO 2 understand algorithm analysis
CO 3 able to create code on financial computation.

SYLLABUS

Modern Finance, Analysis of Algorithms, Basic Financial Mathematics, Bond Price Volatility, Term Structure of Interest Rates, Option PricingModels, Continuous-Time Financial Mathematics, Numerical Methods

REFERENCES

1. Yuh Dauh Lyuu, 2004, Financial Engineering and Computation: Principle Mathematics, Algorithm, Cambridge University Press, UK.
2. Higham, D. J., 2004, An introduction to financial option valuation: Mathematics, Stochastics and Computation, Cambridge University Press, UK.

MMM 5514 ECONOMETRICS ANALYSIS OF FINANCIAL DATA (3 CU)
PREREQUISITES
No Prerequisite

LEARNING OUTCOMES
After completing this course, the students should be able to:
CO 1 Students should understand various econometrics model for analyzing financial data
CO 2 Student should be able to use R, EViews or other software to apply the econometrics model for analyzing financial data
CO 3 Student should be able to analyze and explains to other people about the output from statistical software

SYLLABUS
Basic statistical analysis using descriptive analysis and graphics, analysis of correlation, simple regression, multiple regression, regression with dummy variable, regression with lag variable; univariate time series analysis, regression model with time series variable (case study: stationary, unit root and cointegrated), vector autoregression, volatility model (ARCH/GARCH and its extension), other advanced models.

REFERENCES
1. Koop. G., 2006, Analysis Of Financial Data, John Wiley & Sons.
2. Tsay, R.S., 2012, An Introduction to Analysis of Financial Data with R, Wiley, New York.
3. Alexander, C., 2001, Market models: A guide to financial data analysis, John Wiley and Sons.
4. Rosadi, D., 2011, Analisa Ekonometrika dan Runtun Waktu Terapan dengan R, Andi Ofset, Yogyakarta.
5. Rosadi, D., 2013, Ekonometrika dan Analisa Runtun Waktu Terapan dengan EViews, Andi Ofset, Yogyakarta.

MMM 5515 BOND PRICE MODELING (3 CU)
PREREQUISITES
No Prerequisite

LEARNING OUTCOMES
After completing this course, the students should be able to:

CO 1. Understand the concept of bonds and their types.
CO 2. Understand factors influencing bond prices.
CO 3. Understand bond yields.
CO 4. Understand various yield models.

SYLLABUS

Extracting yield curves from bond prices, Affine models, Merton's model, Vasicek's model, The Cox-Ingersoll-Ross model, Heath-Jarrow-Morton models, The measurement and management of interest rate risk, Mortgage-backed securities.

REFERENCES

1. Tuckman B, 2002, Fixed Income Securities, John Wiley & Sons. New York.
2. Fabozzi, F.J., 2007, Fixed Income Analysis, John Wiley & Sons, Inc.
3. Kellison, S. G., 2009, The Theory of Interest, John Wiley & Sons. New York.
4. Higham, D. J., 2004, An Introduction to Financial Option Valuation, Cambridge University Press, Cambridge.

MMM 5516 OPTION PRICING AND FINANCIAL MODELING (3 CU)

PREREQUISITES

No Prerequisite

LEARNING OUTCOMES

After completing this course, the students should be able to:
CO 1. Knowing and analyzing option theory.
CO 2. Understanding and comprehending the theory of option pricing, including the Black-Scholes model and Binomial model.
CO 3. Applying CO 1 and CO 2 in options trading.

SYLLABUS

This course is a course that discusses the application of mathematics in finance. Topics include interest material, interest rates, simple interest, compound interest, continuous interest, accumulated value, present value, discount rate. This course also studies the series of payments or annuities, basic annuities, advanced annuities, perpetuities, amortization, sinking funds. In addition, this course also studies the determination of bond prices, yields, reinvestment of interest rates, net present value.

Option valuation theory, various options, volatility and estimation. Market mechanization in options trading. Strategies in options trading. The option price valuation model uses simulation techniques.
Black Scholes Merton (BSM) model, BSM formula. Gram Charlier's expansion B-S model, Application of the Black Scholes model to the options market. Performance analysis of the Black Scholes model. Data analysis using R and Matlab software.

REFERENCES

1. Wilmott, P., 2007, Introduces Quantitative Finance, John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex PO19 8SQ, England.
2. John C Hull, 2005, Options, Futures, and Other Derivatives, 6th Edition, Prentice Hall.

MMM 5520 CREDIBILITY THEORY (3 CU)

PREREQUISITES

No Prerequisite

LEARNING OUTCOMES

After completing this course, the students should be able to:

CO 1. Understand the concept of conditional probability and measures of conditional probability distributions.

CO 2. Undertand Bayesian methods and the concept of Bayesian inference.

CO 3. Comprehend existing credibility methods and having insights into their development.

SYLLABUS

Conditional probabilities and conditional random variables, Empirical distribution, Bayesian concept, Bayesian estimation and inference, full credibility and partial credibility, Buhlmann credibility, Buhlmann-Straub credibility, Empirical credibility, non parametric and semi-parametric credibility

REFERENCES

1. Klugman, S.A., Panjer, H.H, dan Willmot, G.E., 2012, Loss Models: From Data to Decision, 4th Edition, Berlin: Wiley.
2. Buhlmann, H. dan Gisler, A., 2005, A Course in Credibility Theory and Its Applications,Hoboken, NJ: Springer.

COURSE SYLLABUS IN STATISTICAL COMPUTATION LABORATORY (5 COURSES)

MMM 6601 CAPITA SELECTA in STATISTICAL COMPUTATION (3 CU)

PREREQUISITES

Have taken/are currently taking Mathematical Statistics I.

LEARNING OUTCOMES

After completing this course, the students should be able to:

CO 1. Able to comprehend the basic concepts of Statistical Computing.
CO 2. Capable of working on current topics in the field of Statistical Computing.
CO 3. Proficient in applying CO2 to issues in the industrial world.

SYLLABUS
Introduction to the concept of statistical computing, Advanced statistical computing topics such as: reproducible research with knitr, pandoc, Rmarkdown, Latex, High-performance computing and big data using R and Hadoop, Robust and multivariate methods in R, Statistical methods for metabolomics data or other current topics in the field of statistical computing.

REFERENCES

1. Martinez, W.L. and Martinez, AR., 2007, Computational Statistics Handbook with MATLAB, Chapman & Hall, New York.
2. Literatur berupa buku dan paper terkait sesuai dengan topik terpilih.

MMM 5601 MACHINE LEARNING (3 CU)
PREREQUISITES
Have taken/are currently taking Mathematical Statistics I.

LEARNING OUTCOMES
After completing this course, the students should be able to:
CO 1. Understand the fundamental concepts in Machine Learning.
CO 2. Understand classical concepts in Machine Learning methods.
CO 3. Conduct a study on the latest methods in Machine Learning research.

SYLLABUS
Introduction to Machine Learning, Classical Machine Learning Methods for Classification, Clustering, and Association, Advanced Study: Research in Machine Learning topics, presentation of several recent machine learning topics.

REFERENCES

1. Hastie, T., Tibshirani, R., Friedman, J., 2016, The Elements of Statistical Learning (2nd Edition), Springer Verlag, New York
2. Provost, F. and Fawcett, T., 2019, Data Science for Business, O'Reilly
3. Ghatak, A., 2019, Deep Learning with R, Springer, London
4. Larose, D.T., Data Mining Methods and Models, Wiley-Interscience, New York
5. James, G., Witten, D., Hastie, T, and Tibshirani, R., 2015, An Introduction to Statistical Learning with Applications in R, Springer, New York.
6. Paper-paper terbaru pada topik ini.

MMM 5610 APPLIED STATISTICAL COMPUTING 1 (3 CU)
PREREQUISITES
No Prerequisite

LEARNING OUTCOMES
After completing this course, the students should be able to:
CO 1. Understand the methodology of statistical computing and its applications.
CO 2. Operate R software for statistical computing and its applications.
CO 3. Analyze the output generated by statistical software for statistical computing and its applications.

SYLLABUS
Introduction to Statistical Computing and Computational Statistics; Introduction to R and Programming using R, Some Statistical computation topics: Numerical methods for moment estimator and maximum likelihood, Random number generation, Monte carlo simulation, Numerical methods (Newton Raphson methods), numerical optimization, Symbolic computation, Machine Learning using, Introduction to Data Science, other topics

REFERENCES

1. Braun..D., 2008, A First Course in Statistical Programming with R, Cambridge University Press.
2. Heiberger, R.M., Neuwirth, E., 2009, R Through Excel: A Spreadsheet Interface for Statistics, Data Analysis, and Graphics, Springer.
3. Martinez, W.L. and Martinez, AR, 2007, Computational Statistics Handbook with MATLAB, Chapman & Hall, New York.
4. Rosadi, D., 2011, Analisa Ekonometrika dan Runtun Waktu Terapan dengan R, Andi Offset, Yogyakarta.
5. Rosadi, D., 2017, Analisa Statistika Terapan dengan R, Gama Press.

MMM 6604 APPLIED STATISTICAL COMPUTING 2 (3 CU)
PREREQUISITES
No Prerequisite

LEARNING OUTCOMES
After completing this course, the students should be able to:
CO 1. Understand the methodology of statistical computing and its applications.
CO 2. Operate Python software for statistical computing and its applications.
CO 3. Analyze the output generated by statistical software for statistical computing and its applications.

SYLLABUS

Introduction to statistical computing, introduction to programing using Python, Statistical analysis using Python in comparison with R, Introduction to Statistical Machine Learning using Python, Hands on application of Statistical Analysis using Python.

REFERENCES

1. Grus, J., 2019, Data Science from Scratch First Principles With Python, 2nd Eds., OReilly, Beijing.
2. Sarmento R. dan Costa, V. 2017, Comparative Approaches to Using R and Python for Statistical Data Analysis, IGI Global Core.

MMM 5604 BUSINESS ANALYTICS (3 CU)

PREREQUISITES

No Prerequisite

LEARNING OUTCOMES

After completing this course the students have ability to :

CO 1. Understand some basic concept related to business analytics

CO2. Use statistical software to do business analytics

CO3. Be able to apply some statistical concepts for business analytics

SYLLABUS

Introduction of some concept: Big Data Technology, Data Mining, Decision System, Business analytics. Introduction to some statistical software to business analytics: R, Rattle, SAS, SPSS, etc, Application of statistical concepts for business analytics

REFERENCES

1. Ledolter, J., 2013, Data Mining and Business Analytics with R, Wiley, John & Sons, New York.
2. Graham Williams, 2011, Data Mining with Rattle and R: The Art of Excavating Data for Knowledge Discovery, Springer, New York.
3. Minelli, M, Chambers, M., and Dhiraj,A. 2013, Big Data, Big Analytics: Emerging Business. Intelligence and Analytic Trends for Today's Businesses, Wiley CIO Series.