MIPA
UGM
Research for
Innovations

CURRICULUM2022

MASTER PROGRAM

FACULTY OF MATHEMATICAL AND NATURAL SCIENCES
UNIVERSITAS GADJAH MADA

CONTACT

Addres

Fakultas MIPA UGM

Sekip Utara BLS 21
Yogyakarta 55281
INDONESIA

Phone and Fax

Phone : (0274) 513339
Fax : (0274) 513339

Online

Email : mipa@ugm.ac.id
Website : mipa.ugm.ac.id

@mipaugm @fmipaugm mipa.ugm.ac.id mipa@ugm.ac.id

PREFACE

DEAN FMIPA UGM

The purpose of education at UGM, especially in the Master's Program within the Faculty of Mathematics and Natural Sciences UGM, is to produce graduates of the Master's Program. They have the competencies stipulated in the Indonesian National Qualifications Framework (KKNI Level 8).

This 2022 Masters Program Curriculum document has been compiled through a relatively lengthy process involving many parties and has been consulted and received input and approval from the Faculty Senate. The stages of curriculum preparation began with the formation of a curriculum drafting team ratified through the Dean's Decree, a survey of students, alumni, and alumni users, followed by an evaluation of the 2017 Curriculum Document for the Master's Program of the Faculty of Mathematics and Natural Sciences UGM. This 2022 Masters Program Curriculum Document refers to other documents, namely UGM Academic Senate Decree Number 08/STVSA/2012 concerning UGM Academic Policy [1], UGM Rector Regulation Number 15 of 2017 concerning UGM Academic Standards [2], 2017 Program Curriculum Document Doctor of Mathematics and Natural Sciences UGM [3], Regulation of the Rector of UGM Number 11 of 2016 concerning Postgraduate Education [4], Addendum to the 2017 Curriculum for Master Program of the Faculty of Mathematics and Natural Sciences UGM in 2021 [5], Regulation of the Rector of UGM Number 18 of 2019 concerning the Implementation of Research-Based Postgraduate Programs (by Research) within UGM [6], Law Number 12 of 2012 concerning Higher Education [7], Presidential Regulation Number 8 of 2012 concerning the Indonesian National Qualifications Framework [8], Permenristekdikti Number 44 of 2015 concerning National Standards of Higher Education [9] , UGM Rector Regulation Number 12 of 2020 concerning Amendments to UGM Rector Regulation Number 11 of 2016 concerning Postgraduate Education [10], UGM Rector Regulation No. 14 of 2020 concerning the Basic Framework for the UGM Curriculum [11], Rector Regulation of UGM Number 7 of 2022 concerning UGM Higher Education Standards [12], Scientific Foresighting of the Faculty of Mathematics and Natural Sciences UGM 2016 [13], Adaptation Document for Educational Disruption in the field of Mathematics and Natural Sciences in the Industrial Age 4.0 of 2019 [14], Strategic Plan Documents of the Faculty of Mathematics and Natural Sciences UGM 2018-2022 [15], Academic Policy Documents of the Faculty of Mathematics and Natural Sciences UGM for 2020-2025 [16], and Permendikbud Number 3 of 2020 concerning National Standards for Higher Education [17].

Dokumen ini akan digunakan sebagai REFERENCES dalam penyelenggaraan Pendidikan Program Magister di seluruh Departemen di Fakultas MIPA UGM mulai Semester I Tahun Akademik 2022/2023. Di sisi lain, dokumen ini merupakan kebijakan yang memerlukan penjabaran lebih lanjut dalam operasionalisasinya. Berlakunya kurikulum sejalan dengan berlakunya dokumen ini dan terbuka untuk revisi minor bila dianggap sangat perlu. Pimpinan Fakultas berkewajiban untuk terus memantau dinamika perubahan kebijakan pemerintah pusat dan UGM terkait kurikulum dan mengubah dokumen kurikulum ini dan pelaksanaannya.

None gading yang tak retak, Pimpinan Fakultas mengucapkan terima kasih kepada semua pihak yang telah memberi masukan pada waktu penyusunan Dokumen Kurikulum ini dan di masa-masa yang akan datang. Terima kasih juga kami sampaikan kepada Senat Fakultas MIPA yang telah membahas dan mengesahkan dokumen ini untuk diberlakukan di Fakultas MIPA UGM.

Yogyakarta, 10 Agustus 2022

Dean of FMIPA UGM

PREFACE

CHAIRMAN OF SENATE
FMIPA UGM

Sebagaimana diatur dalam Pasal 47 ayat (1) huruf a Peraturan Pemerintah Republik Indonesia Nomor 67 Tahun 2013 Tentang Statuta Universitas Gadjah Mada, Pasal 84 ayat (1) huruf a Peraturan Majelis Wali Amanat Universitas Gadjah Mada Nomor 4/SK/MWA/2014 Tentang Organisasi dan Tata Kelola (*Governance*) Universitas Gadjah Mada, dan Pasal 5 ayat (2) huruf f Peraturan Rektor Universitas Gadjah Mada Nomor 809/P/SK/HT/2015 Tentang Organisasi Dan Tata Kelola (*Governance*) Fakultas di Lingkungan Universitas Gadjah Mada, Senat Fakultas bertugas memberi persetujuan atas usulan perubahan kurikulum dan memberi pertimbangan atas penyelenggaraan fakultas.

This 2022 Masters Program Curriculum document has been compiled through a fairly long process and involves many parties and has been consulted and received input and received approval from the Faculty Senate. The stages of curriculum preparation began with the formation of a curriculum drafting team, which was ratified through the Dean's Decree, a survey of students, alumni, and alumni users, followed by an evaluation of the 2017 Curriculum Document for the Master's Program of the Faculty of Mathematics and Natural Sciences UGM. This 2022 Masters Program Curriculum Document refers to other documents, namely the Decree of the UGM Academic Senate Number 08/STVSA/2012 concerning UGM Academic Policy [1], UGM Academic Standards of 2017 [2], 2017 Curriculum Documents for Masters Program Faculty of Mathematics and Natural Sciences UGM [3], UGM Chancellor Regulation Number 11 of 2016 concerning Postgraduate Education [4], 2017 Curriculum Addendum for Masters Program Faculty of Mathematics and Natural Sciences UGM in 2021 [5], UGM Rector Regulation Number 18 of 2019 concerning Implementation of Research-Based Postgraduate Programs (by Research) at UGM [6], Law Number 12 of 2012 concerning Higher Education [7], Presidential Regulation Number 8 of 2012 concerning the Indonesian National Qualifications Framework [8], Permenristekdikti Number 44 of 2015 concerning National Standards of Higher Education [9], Rector of UGM Regulation Number 12 2020 concerning Amendments to UGM Rector Regulation Number 11 of 2016 concerning Postgraduate Education [10], UGM Chancellor's Regulation Number 14 of 2020 concerning Basic Framework r UGM Curriculum [11], UGM Chancellor Regulation Number 7 of 2022 concerning UGM Higher Education Standards [12], Scientific Foresighting of the Faculty of Mathematics and Natural Sciences UGM 2016 [13], Documents of Adaptation to Disruption of Education in Mathematics and Natural Sciences in the Industrial Era 4.0 Year 2019 [14], 2018-2022 Faculty of Mathematics and Natural Sciences UGM Strategic Plan Document [15], Academic Policy Document of Faculty of Mathematics and Natural Sciences UGM for 2020-2025 [16], and Permendikbud Number 3 of 2020 concerning National Standards for Higher Education [17].

This 2022 Masters Program curriculum document must be a reference in the implementation of Masters Program Education in all Departments at the Faculty of Mathematics and Natural Sciences UGM starting in Semester I of the 2022/2023 Academic Year. This document is a policy that requires further elaboration in its operation. The application of the curriculum is in line with the validity of this document and is open to minor revisions if deemed necessary.

Finally, we hope that, with the preparation of this 2022 Curriculum Document, all the implementation of Master Program Education in all Departments at the Faculty of Mathematics and Natural Sciences UGM can run smoothly so that FMIPA UGM will become a center of excellence and a national and international reference center.

Thank you.

Yogyakarta, 10 Agustus 2022

Chairman of the Senate

ENDORSEMENT PAGE

This 2022 Curriculum Document for the Master's Program of the Faculty of Mathematics and Natural Sciences UGM was ratified on August 10, 2022 by:

Chairman of the Senate FMIPA UGM,	Dean of FMIPA UGM
Prof. Drs. Mudasir, M.Eng., Ph.D.	Prof. Dr. Eng. Kuwat Triyana, M.Si.

CONTENTS

BAB 1 FACULTY

1.1 INTRODUCTION

The Faculty of Mathematics and Natural Sciences at Gadjah Mada University was inaugurated on September 19, 1955, with the Decree of the Minister of Education, Teaching and Culture dated September 15, 1955, Number 53759 / Kab. In this decree, the faculty is still a joint faculty with the Faculty of Engineering called the Union of The Faculty of Exact and Natural Sciences and the Faculty of Engineering. On September 1, 1956, the Faculty of Exact and Natural Sciences (abbreviated as FIPA in Bahasa) began to separate itself from the Faculty of Engineering.

At the time of its inauguration as the Faculty of Unity, FIPA only had one department, which then was called the Department of Exact Sciences. This department has existed since 1950 as a department in the Civil Engineering Section of the Faculty of Engineering. When FIPA began to stand alone as a Faculty on September 1, 1956, a new department began to be opened, which at that time was called the Natural Sciences Section, then on September 1, 1960, plus one more department, namely the Chemical Sciences section. Starting on December 28, 1982, the name of FIPA was changed to FMIPA (Faculty of Mathematics and Natural Sciences) and had 3 Departments, namely the Department of Physics, the Department of Chemistry, and the Department of Mathematics.

Since it was still a joint faculty until it separated from the Faculty of Engineering, offices and lecture activities were still held in the old Faculty of Engineering building on Jetisharjo Street No. 1 Yogyakarta. Basic physics practicum activities and workshops are still held in the old Faculty of Medicine complex in Mangkubumen.

Until 1986, the Faculty of Mathematics and Natural Sciences had a physical infrastructure building covering an area of 13,925 m2 and a Library with 10,529 books and a total of 4,297 book titles. In 1987, through the development with the help of the World Bank Project IX, library facilities have been increased to 13,929 books with 5,954 titles, and the physical infrastructure of the building was also added with 1369 m2 faculty office rooms and 3764 m2 of chemical laboratory buildings so that the total becomes 19,058 m2.

With the construction of the faculty administration building and chemistry laboratory in North Sekip by the World Bank IX Project, starting in February 1989, the FMIPA Administrative Office, the Department of Physics and the Department of Chemistry have occupied the area of the new building in North Sekip. In February 1994, there was a fire disaster in the Sekip Unit III building. One-third of the building, an area of approximately 1200 m2, was heavily damaged and could no longer be used. The entire Organic Chemistry laboratory, Computing laboratory and Mathematics Postgraduate Program Library room, along with all its contents in the form of laboratory equipment, practicum and research materials, books, magazines, journals and others, were destroyed by fire.

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

In early 2003, a three-story building covering an area of 1,506.90 m2 was completed, bringing the total building area to 22,552 m of the new building for the implementation of lectures, computer laboratories and student internet service centers.

The Master of Science (Masters) program originally only covered the fields of Physics and Chemistry, starting from the 1992/1993 academic year, plus the field of mathematics following the decree. DIKTI No. 128/DIKTI/Kep/1992. The field of physics includes geophysical interests. In the field of Mathematics Studies since April 11, 1992, an interest in computer science was opened. Meanwhile, in the 1999 academic year, the Faculty of Mathematics and Natural Sciences also opened a Master's Program in Computer Science with SK DIKTI No. 259 / DIKTI / KEP / 1999, dated May 27, 1999.

In 2010, the proposal for establishing the Department of Computer Science and Electronics (abbreviated as JIKE in Bahasa) submitted by the faculty in 2006 was finally approved by UGM. In the organizational structure, JIKE houses two S1 study programs, namely the Electronics and Instrumentation Study Program, which moved from the Physics Department, and the Computer Science Study Program, which moved from the Department of Mathematics and the Master Program and S3 Computer Science.

To streamline and streamline the performance of all units to accelerate the realization of the vision and mission of FMIPA, a new FMIPA SOTK was established through the UGM Rector's Decree No. 809 / P / SK / HT / 2015, which in Article 28 is used "Department" as a unit under the faculty to replace the 'Department". Through Decree Number 580 / UN1. P/KPT/HUKOR/2022, the Rector of UGM set a special SOTK for FMIPA UGM, as shown in **Figure 1.1**.

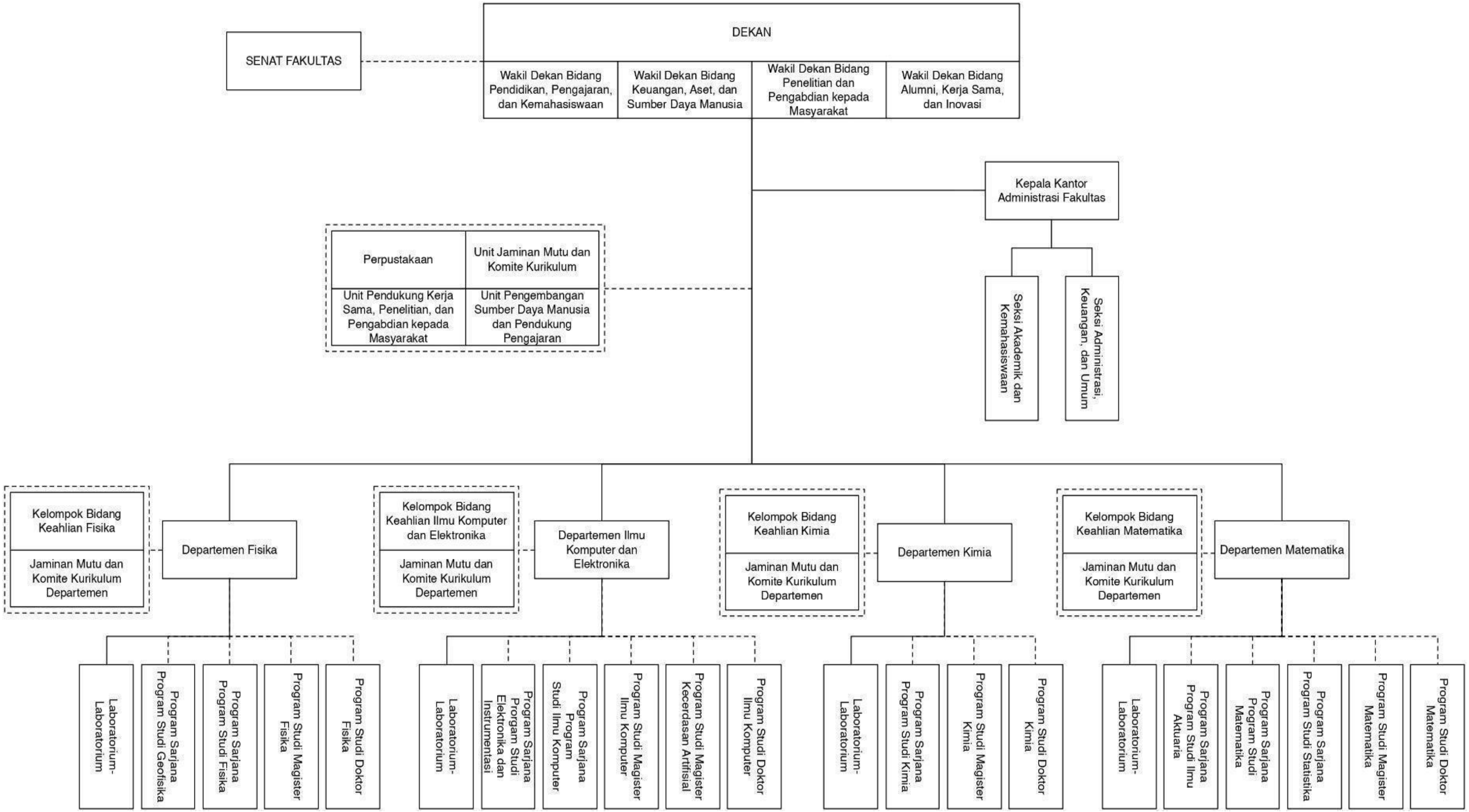

Figure 1.1 FMIPA UGM Organizational Structure

To realize its mandate, the Faculty of Mathematics and Natural Sciences UGM refers to and follows the Basic Values set by the University as stated in the Strategic Plan Document of Gadjah Mada University for 2018-2022. The fundamental values are as follows:

1. Pancasila's values include divinity, humanity, unity, peoplehood, and justice.
2. Scientific values that include the value of universality and objectivity of science, academic freedom and academic pulpit, appreciation of reality and truth for civility, expediency, and happiness.
3. Cultural values that include tolerance, human rights, and diversity.

1.2 VISION

The vision of the Faculty of Mathematics and Natural Sciences UGM, as stated in the Strategic Plan and Operational Plan of the Faculty of Mathematics and Natural Sciences UGM 2018-2022, is that in 2037 it will become a nationally superior and internationally leading faculty that develops mathematics, physics, chemistry, as well as computer science and electronics for the welfare of the nation imbued with the nation's cultural values based on Pancasila.

1.3 MISION

The missions of the Faculty of Mathematics and Natural Sciences UGM, as stated in the Strategic Plan and Operational Plan of the Faculty of Mathematics and Natural Sciences UGM 2018-2022, are as follows:

1. Develop international standard education in mathematics, physics, chemistry, computer science, and electronics by utilizing the most significant amount of research results.

2. Carry out superior, innovative, and directed research in mathematics, physics, chemistry, computer science and electronics for the welfare of the nation in particular and humankind in general.

3. Carry out community service by utilizing the maximum research results in mathematics, physics, chemistry, computer science, and electronics to solve problems in the future and for humankind.

4. Develop sustainable resources, organization and governance, and supporting facilities.

1.4 PURPOSE

The goal to be achieved is the realization of the Faculty of Mathematics and Natural Sciences UGM as part of Gadjah Mada University to become an excellent Faculty in Indonesia with international achievements and reputation through:

1. Education in the Fields of Mathematics, Physics, Chemistry, as well as Superior and Innovative Computer Science and Electronics, namely international standard education that is cross-disciplinary, innovative, soft skills, and supported by the latest information technology with postgraduate programs as the backbone in producing graduates who are healthy, virtuous, confident, competitive, innovative, and entrepreneurial in spirit, and responsible for the nation.

2. Research in the fields of Mathematics, Physics, and Chemistry, as well as Superior, Innovative and Directed Computer Science and Electronics, namely research in these fields that is environmentally sound, becomes a national and international reference and can provide solutions to the problems of the nation and humankind, based on the advantages of human and natural resources and local wisdom by involving stakeholders following the faculty's research master plan.

3. Superior and Innovative Community Service based on expertise in the fields of Mathematics, Physics, Chemistry, as well as Computer Science and Electronics, namely scientific-based community service, appropriate technology, and advocacy in these fields, which can encourage the independence and welfare of the community in a sustainable manner, by making the campus a vehicle for the application of science and technology innovation for the community, and implementing a product development management system to support rotation of research results

4. Development of Resources, Organization and Governance as well as Cooperation that is equitable, transparent, participatory, and accountable to support the effectiveness and efficiency of resource utilization, based on an integrated information technology system to support the implementation of an adaptive learning process to Industry 4.0.

1.5 GOALS AND ACHIEVEMENT STRATEGIES

Goals and Achievement Strategies for Goal 1

Objective 1: Superior and Innovative Mathematics, Physics, Chemistry, and Computer Science and Electronics Education, namely international standard education that is cross-disciplinary, innovative, soft skills, and supported by the latest information technology with postgraduate programs as the backbone in producing graduates who are healthy, virtuous, confident, competitive, innovative, and entrepreneurial in spirit, and responsible for the nation.

Table 1.1 Objectives and Achievement Strategies for Goal 1

Goal	Achievement Strategy
1. Improving the quality of the new student admission system based on academic ability, diversity, independence, and inclusion.	1.1 Strengthening the proportion of new students through affirmation programs and KIP (Kartu Indonesia Pintar), achievements, and cooperation.
	1.2 Strengthening the strategy and system of promoting foreign student admissions.
2. Creating and improving the culture of quality education and learning processes.	2.1 Strengthening the outcome-based education-based curriculum, KKNI, and SN-DIKTI.
	2.2 Strengthening MOOC e-learning-based learning.
	2.3 Dissemination of knowledge to strengthen external learning resources through knowledge channels and science towers (abbreviated as KPMI in Bahasa).
	2.4 Strengthening the mentoring/counselling system and institutional career coaching of new students and recent graduates.
	2.5 Strengthening of infrastructure (physical and non-physical) of education and learning.
	2.6 Increased student achievement at national and international levels.
	2.7 Strengthening the online-based student service system (SIA, library, and others).
	2.8 Improving the quality of study programs.
3. Develop education and learning across disciplines and exposure to global competencies.	3.1 Development of cross-disciplinary courses based on synergy across science fields, study programs, and faculties.
	3.2 Development of global competency exposure courses to improve student competence.
4. Making postgraduate education the backbone of the Tridharma of Higher Education.	4.1 Improving the quality of student research through participation in lecturer research,
	4.2 Increase in the number of scholarships for graduate students (domestic and overseas).
	4.3 Increase in the number of *student mobility* graduate students.
5. Internationalization of study programs.	5.1 Develop a visiting professor program.
	5.2 Development of *Massive Open Online Course* (MOOC) with overseas college partners.
	5.3 Improve *double degree programs*, *dual degree programs*, and *twinning programs* with leading universities abroad
6. Improving the spirit of innovation and social entrepreneurship of students.	6.1 Develop *soft skills*, character, and entrepreneurial spirit.
7. Improving the healthy lifestyle of students	7.1 Educating students on healthy lifestyles

Goals and Achievement Strategies for Goal 2

Objective 2: Research in the Fields of Mathematics, Physics, Chemistry, and Superior, Innovative and Directed Computer Science and Electronics, namely research in these environmentally sound fields, become national and international references and can provide solutions to the problems of the nation and humankind, based on the advantages of human and natural resources and local wisdom by involving stakeholders following the faculty's research master plan.

Table 1.2 Objectives and Achievement Strategies for Goal 2

Goal	Achievement Strategy
1. Develop multidisciplinary research with environmental insights and local values of excellence to provide solutions to problems of society, nation, and state	1.1 Development of a multi, inter, and cross-disciplinary research culture based on the Social Humanities, Agro, Health, and/or Science and Technology cluster through the institutions of Faculties, Schools, and Centers of Study
	1.2 Development of comprehensive research (various aspects) of maritime-island countries.
2. Developing innovative research based on cultural wisdom that has a substantial impact on the development of science and technology for the benefit of the nation, state, and humanity.	2.1 Increase in the number of publications of research results in journals.
	2.2 Increased amount of intellectual property including copyright and geographical indications based on cultural wisdom and natural property.
	2.3 Increased utilization of research results for strategic policy and industrial purposes.
	2.4 Increased profile of capacity, activity, and research expertise internally and externally.
	2.5 Increase in the number of overseas partner researchers.
3. Improve research funding capabilities by looking at external stakeholders.	3.1 Enhanced capabilities and excellence of multi-, inter- and cross-disciplinary competitive research to support success in obtaining funding from national and international sources.
	3.2 development and enhancement of ongoing strategic cooperation with research funding partners from the government, private and industrial sectors.
	3.3 Ordering and capacity building of research facilities and laboratories in an integrated and sustainable manner.
4. Increase research institutions and capacity of research facilities and laboratories	4.1 Increased implementation of national and international seminars

Goals and Achievement Strategies for Goal 3

Objective 3: Superior and Innovative Community Service based on expertise in the fields of Mathematics, Physics, Chemistry, and Computer Science and Electronics, namely scientific-based community service, appropriate technology, and advocacy in these fields, which can encourage independence and community welfare in a sustainable manner, by making the campus a vehicle for implementing science and technology innovation for the community, and implementing a product development management system for the community support the distribution of research results.

Table 1.3 Objectives and Achievement Strategies for Goal 3

Goal	Achievement Strategy
1. Become a strategic partner of the government to increase productivity and *community-driven* welfare.	1.1 Increasing FMIPA's participation in programs within the framework of UUK DIY and *Jogja Cyber Province*
	1.2 Participate in the development of 3T areas/regions based on community service.
2. Developing FMIPA as a vehicle for the application of science and technology for the wider community.	Increasing the number of applications of science and technology developed by FMIPA for communication / industry / business / government.
3. Increasing the reach and quality of community service through the development of entrepreneurship and social care.	Organizing community coaching and training to produce commercial products based on appropriate technology and local resources as well as getting access to funding opportunities for MSMEs through improving the quality of community service implementation in a sustainable manner.
4. Building synergy with alumni networks in the regions to strengthen access to community service	Increasing synergy between FMIPA and alumni in the regions through various community service activities managed by alumni.
5. Increasing the role of FMIPA as a spring for inspiring community service.	Increasing the reach and quality of dissemination of FMIPA community service activities.

Goals and Achievement Strategies for Goal 4

Objective 4: Development of Resources, Organization and Governance as well as Equitable, transparent, participatory, and accountable Cooperation to support the effectiveness and efficiency of resource utilization, based on an integrated information technology system to support the implementation of an adaptive learning process to Industry 4.0.

Table 1.4 Objectives and Achievement Strategies for Goal 4

Goal	Achievement Strategy
Human Resources	
1. Develop an HR admission system.	1.1 Planning and procurement of lecturers based on the development of scientific fields.
	1.2 Planning for the procurement of educational personnel based on the strategic objectives of the University.
2. Develop an employee career system.	2.1 Development of employee career management.
	2.2 Development of the quality and competence of lecturers through further studies and management of functional promotion.
	2.3 Development of the quality and competence of educational personnel.
	2.4 Development of an integrated kerier information system (promotion/ rank) of lecturers.
3. Health-promoting faculty	3.1 Improving the health of lecturers and faculty education staff.
	3.2 Improvement of the quality of the faculty canteen.
Physical and Environmental Infrastructure	
4. Improving integration in facility management for service optimization.	4.1 Integrated management and utilization of building facilities, laboratories, green open spaces, sports facilities, and parking bags in an integrated manner for the improvement of educational services, research, and community service.
	4.2 Provision of public space facilities for the interaction and connectivity of the academic community across KPTU, faculties, schools, study centers, and other work units.
	4.3 Completion of security tools based on current technology and standard operating procedures in the face of emergencies in each facility and its environment.
	4.4 Completion of building access equipment and facilities for the academic community with special needs.
Cooperation and Alumni	
5. Increase strategic cooperation to accelerate the development of education, research results,	5.1 Improving the quality of sustainable strategic cooperation with government, private, and national industry partners in the fields of education, research, and community service.

innovation in science, technology, and culture	5.2. Development and improvement of a network of continuous strategic cooperation with international partners to facilitate joint research, professor exchanges, student exchanges, summer classes, dual degree programs, international academic exposure, and the provision of its funding sources.
6. Increasing synergy and the contribution of alumni in strengthening the Tridharma of higher education	Development and improvement of the network of strategic cooperation between FMIPA, alumni and Kagama in order to increase the role of alumni and Kagama towards strengthening the Tridharma of higher education.
7. Develop programs to facilitate the creativity and synergy of research results that are continued in downstreaming or incubation.	*Start-up business* initiated by the academic community and / or alumni developed through the incubation process at FMIPA.
Governance and Institutions	
8. Strengthening the culture of service and superior performance through strengthening bureaucratic reforms.	Improving the quality of the excellent service system to encourage human resources with positive work, service spirit, integrity, and professionalism, as part of the implementation of *Good University Governance.*
9. Institutional strengthening in order to achieve international standard faculties.	9.1. Feasibility studies, preparation and establishment of new postgraduate courses of study.
	9-2. Feasibility study, preparation and establishment of a new scientific laboratory / group.

1.6 LEARNING PROCESS

A Syarat Input Mahasiswa

To maintain the quality of input for students in the Master's study program at FMIPA UGM, the selection is carried out strictly, starting from registration at the university to the study program. The selection carried out at the university includes:

1. S1 GPA score for Regular Master's program

S1 GPA (Scale 4 or equivalent)	Accreditation of the Original Study Program
≥ 2.50	Applicants who graduate from superior or A accredited undergraduate or applied undergraduate study programs; or
≥ 2.75	Applicants who graduate from accredited undergraduate or applied undergraduate study programs either once or B; or
≥ 3.00	Applicants who graduate from either accredited undergraduate or applied bachelor's study programs or C.

2. S1 GPA score for Master by Research program

S1 GPA (Scale 4 or equivalent)	Accreditation of the Original Study Program
≥ 3.00	Applicants who graduate from an accredited undergraduate or applied bachelor's study program are at least once or B.

3. Have a minimum PAPs, TKDA PLTI, or TPA Bappenas value of 450.
4. Have an English proficiency score of at least TOEFL 400 or AcEPT 149 (or it is equivalent).
5. Have recommendations from 2 (two) people who know applicants.
6. Attach a pre-research proposal.
7. Attach proof of publication (if any).
8. Have recommendations that come from 2 (two) people who know applicants.

Each study program can set higher conditions than those mentioned above, conducting substance tests following the scientific field of the study program and interviews

B Learning Process Standards

Essential items in the learning process carried out include:

1. Characteristics of the learning process, consisting of an interactive, holistic, integrative, scientific, contextual, thematic, practical, collaborative, and student-centered nature.
2. Planning the learning process, compiled for each course and presented in the program plan of semester learning activities (RPKPS);
3. Implementation of the learning process, each course is carried out according to the RPKPS with the characteristics of each course; and
4. Student learning load, one credit is equivalent to 170 (one hundred and seventy) minutes of learning activities per week per semester. A semester is a unit of time for practical learning activities for 16 (sixteen) weeks

In learning, each Master's study program is given the flexibility to design, assign, organize, evaluate and develop learning methods that essentially have the following characteristics:

a) Student-centered learning improves self-learning, verbal, and academic and rational thinking ability.
b) The use of information technology to enrich science through structured and planned assignments.
c) Interaction lectures more actively involve students in the learning process in the classroom.
d) Active learning methods encourage students to be more creative and active in exploring various scientific sources.
e) Prioritizing creative and rational ways of thinking to answer every problem

and phenomenon, and

f) Enrichment of evaluation methods using various forms of assignment, individual and group.

All lecturers who teach the Master's study program must have a Doctoral degree in the relevant field and have an available position as at least an associate professor.

C Semester Credit System

1. 1 (one) credit in the learning process in the form of lectures, responses, or tutorials, consisting of:
   a. face-to-face activities of 50 (fifty) minutes per week for one semester;
   b. structured assignment activities of 60 (sixty) minutes per week for one semester; and
   c. independent activities of 60 (sixty) minutes per week for one semester.

2. 1 (one) credit in the learning process in the form of seminars or other similar forms, consisting of:
   a. face-to-face activities of 100 (one hundred) minutes per week for one semester, and
   b. independent activities of 70 (seventy) minutes per week for one semester.

3. 1 (one) credit in the learning process in the form of practicum, studio practice, workshop practice, field practice, research, community service, and other similar learning processes, equivalent to 170 (one hundred and seventy) minutes per week for one semester.

D Study Period Load

The period and study load of the implementation of the Master's education program at FMIPA UGM refers to the Minister of Research, Technology and Higher Education No. 44 of 2015 and the regulation of the Rector of Gadjah Mada University No. 11 of 2016, and the Minister of Education and Culture No. 3/2020 concerning SN-Dikti, namely.

1. The curriculum is designed, so students complete their Master's studies within 2 (two) years.
2. If within 2 (two) years the student has not been able to complete their studies, then students are allowed to extend their studies for 1 (one) semester after getting a recommendation from the thesis supervisor. The study period can be extended for the next 1 (one) semester accompanied by a statement letter approved by the thesis supervisor that in the next 1 (one) semester, students can complete their studies.
3. After an evaluation by the study program manager, the first warning letter (SP 1) will be given at the end of semester 4, SP 2 at the beginning of semester six and SP 3 at the beginning of semester 8.
4. If within 4 (four) years they have not been able to complete their studies,

then students are required to resign from the Master's study program of FMIPA UGM.

The amount of study load that must be taken by a Master's student at FMIPA UGM is a minimum of 36 credits, consisting of compulsory courses, elective courses and theses. The student's study load for each semester is set at the beginning of the semester through consultation with the Academic Supervisor (DPA), considering the success of the previous semester's studies. The specified study load can be fulfilled by taking compulsory courses or elective courses by paying attention to the fulfilment of prerequisite courses.

The study load of a Master's student every semester needs to be determined by considering two factors, namely the individual ability of the student concerned and the average study time a day. If a student can normally work 6-8 hours during the day plus 2 hours at night, then in one week or five working days, students can work for 48-60 hours. For the first semester, the study load of Master's students is between 15-20 credits. According to the following table, IP in the first 1 (one) semester is used to determine the study load that can be taken in the next semester (semester 2) and so on.

MASTER PROGRAM	
PREVIOUS SEMESTER IP	**MAXIMUM CREDITS THAT CAN BE TAKEN**
≥ 3.50	20
3,00 – 3,49	17
< 3.00	12

Each study program can set stricter conditions than those mentioned above. Each study program determines the types of courses that must be taken by students. Especially students participating in the Double / Dual Degree Program are allowed to take a maximum of 20 credits of courses and an 8-credit thesis from the first semester.

E Academic Guidance and Final Project

For each Master's student, an Academic Supervisor (DPA) is assigned. DPA is a lecturer who plays a role in guiding students who are their guidance so that they are smooth in planning their studies every semester. At the beginning of each semester, students need to consult with the DPA to get academic guidance regarding filling out a Study Plan Card (KRS). In addition, students can consult at any time with the DPA to resolve various academic-related issues. In KRS, all courses that students will take for one semester are contained following applicable regulations. Academic supervisors are proposed by the study program and determined by the faculty.

In addition to the DPA, each Master's student has 1 or 2 Thesis Supervisors (DPT) who guide students whose guidance is related to the thesis preparation. The guidance starts from determining the title of the thesis, preparing proposals, conducting research, processing data, preparing publication manuscripts, preparing the thesis, and preparing thesis exams. Each student is provided with a logbook to record all research activities. All thesis supervisors must have a doctoral degree in the relevant field with an available position of at least an associate professor (Law No. 12 of 2012). The thesis supervisor is proposed by the study program and determined by the faculty.

F Academic Leave

The residency requirement for Master's students is one year after the first registration. Every Master's student who, for some reason, cannot take part in educational activities for one semester is required to apply for an academic leave permit with the knowledge of the DPA / thesis supervisor before the lectures in the current semester begin. Students who do not participate in educational activities without a permit for academic leave are still considered for their study period and are still required to pay UKT (tuition fee).

Students can apply for academic leave for acceptable reasons after completing educational activities for the first year starting when they are registered as Masters's students at FMIPA UGM. Academic leave is given for 1 (one) semester and can be extended for the next 1 (one) semester. The total length of the academic leave of Master's students is 2 (two) semesters.

1.7 COOPERATION PROGRAM

Master's Program under the umbrella of joint, double, and dual degree cooperation programs follow the agreement in the relevant cooperation document. In addition to the cooperation program, the Faculty of Mathematics and Natural Sciences supports the development of the Master Study Program, for example, through the Fast Track program.

1.8 ASSESSMENT METHODS

A Learning Assessment Standards

Assessment reporting in the form of student success qualifications in taking a course stated in the range of:

1. The letter A is equivalent to the number 4 (four);
2. The letter A- is equivalent to the number 3.75 (three point seven five);
3. The letter A/B is equivalent to the number 3.5 (three point five);
4. The letter B+ is equivalent to the number 3.25 (three comma two five);
5. The letter B is equivalent to the number 3 (three);
6. The letter B- is equivalent to the number 2.75 (two point seven five);
7. The letter B/C is equivalent to the number 2.5 (two point five);
8. The letter C+ is equivalent to the number 2.25 (two commas two five);
9. The letter C is equivalent to the number 2 (two);

10. The letter C- is equivalent to the number 1.75 (one point seven five);
11. The letter C/D is equivalent to the number 1.5 (one point five);
12. The letter D+ is equivalent to the number 1.25 (one point two five);
13. The letter D is equivalent to the number 1 (one); or
14. The letter E is equivalent to the number 0 (zero).

The method of evaluating the learning of courses is carried out through and is not limited to the components:

a) Midterm exam (UTS).
b) End-of-semester exams (UAS).
c) Structured assignments, either individual or group.
d) Quizzes or tests at the beginning or at the end of a lecture.
e) Case-based learning.
f) Problem-based learning.

B Thesis Exam

Each study program regulates the requirements for submitting a thesis exam. Especially for the Master by Research program, already has papers in scientific in reputable international journals that are recognized by the study program. The thesis may consist of proposals, research work, presentations, publications, thesis seminars, thesis manuscripts, and thesis exams. The weight of each component and the mechanism for conducting the thesis exam are determined by the study program with a load range of 8 - 12 credits.

C Repetition and Elimination of Courses

Course scores are declared passed if the grades obtained are at least C. Students who have not met the minimum GPA requirements can improve by repeating or taking new courses. Students have the right to delete courses with the rule of eliminating credits for elective courses, a maximum of 10% of the total number of credits for courses that have been taken.

D Evaluation of Study Results

The merit index (IP) is taken into account through the following formula:

$$IP = \frac{\sum K_i N_i}{\sum K_i}$$

with K_i and N_i each is the number of credits and the weight of the course grades .
Ki Nii

Study results are evaluated in the first 1 (one) year, at the end of the study level and at the end of the study deadline based on the number of credits taken and the IP obtained. Students can continue their Master's studies if, within the first 1 (one) year, they have taken a minimum of 16 credits with a minimum GPA of

3.00.

Students can be declared graduated in the **Regular Masters's program** if they meet the following conditions:

1. Have taken the requirement for the minimum number of graduation credits following the provisions of the study program concerned (minimum 36 credits), which includes all courses required by the study program and thesis (8 credits).
2. Cumulative IP ≥ 3.25.
3. The final project score (Thesis) is at least B.
4. Have a minimum TOEFL score of 450 (AcEPT 209) and a minimum TPA / PAPS of 500 (as a judicial requirement). TOEFL/TPA scores (or equivalent) are valid during the Master's study program.
5. The supervisor and the examining team have endorsed the thesis manuscript accompanied by the published manuscript.
6. Each publication must include the name of the thesis supervisor and the supervisor from UGM as the corresponding author.

Students can be declared passed in the **Master by Research program** if they meet the following conditions:

1. It Already has one paper published in a reputable international journal.
2. Have taken the requirement for the minimum number of graduation credits following the provisions of the study program concerned (minimum 36 credits), which includes all courses required by the study program and thesis (8 credits).
3. Cumulative IP ≥ 3.25.
4. The final project score (Thesis) is at least B.
5. Have a minimum TOEFL score of 450 (AcEPT 209) and a minimum TPA / PAPS of 500 (as a judicial requirement). TOEFL/TPA scores (or equivalent) are valid during the Master's study program.
6. The supervisor and the examining team have endorsed the thesis manuscript accompanied by the published manuscript.

The graduation predicates for the Master by Research and Regular programs are as follows:

a) Graduates obtain the Cumlaude predicate (the predicate of graduating with honours) if the person concerned has (three point seven five) with a maximum study period of 5 semesters (30 months).IPK>3,75
b) Graduates obtain a Very Satisfactory predicate (high graduation predicate), if the person concerned has a GPA at the following interval range: .3,51≤IPK≤3,75
c) Graduates obtain a Satisfactory predicate (moderate graduation

predicate), if the person concerned has a GPA in the following interval range: .3,25≤IPK≤3,50

The publication requirements for students of the **Master by Research** program are as follows:

a) Have produced at least 1 (one) publication accepted in a reputable international scientific journal or have produced 2 (two) publications received in the proceedings of a reputable international seminar / conference;
b) The resulting publication can be in the form of a review article (review article) derived from research results related to the topic of the thesis and not necessarily as the first author;
c) Each publication must include the name of the thesis supervisor and supervisor from UGM as the corresponding author.

1.9 FACILITIES AND INFRASTRUCTURE

The means to organize the teaching and learning process, reference books, and laboratory equipment are sufficient. The availability and adequacy of the means to conduct world-level research publications for the Materials Sciences, Computing, Mathematics, Chemistry, Computer science and Physics groups is already very good. This can be seen from the type 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 computing programs such as Ferrari computers, Wx maxima, Miktek and others.).

The indicator of adequacy is reflected in the many international publications that have been successfully carried out and the establishment of research cooperation forums from both domestic and foreign institutions. The system needed to maintain and utilize this equipment has been made so that financially and scientifically, the equipment has high sustainability and can finance independently. In addition, the support of laboratory facilities and service institutions in the UGM environment can be very easily accessed for the research interests of all undergraduate, master and doctoral level students. The laboratories and institutions in question include Integrated Research and Service Laboratory (LPPT), Data and Information Source Center (PSDI), which was formerly called the Information and Communication Technology Service Center (PPTIK), INHERENT Project, Postgraduate Library and others.

For exploratory research in various fields of interest to lecturers, the available and adequate tools described above are very good. However, it is undeniable that international publications in certain fields such as field research: synthesis, analysis etc. still require the help of analysis services both using equipment from other agencies in Indonesia and abroad by utilizing sophisticated equipment as a force to collaborate with the principle of mutualistic symbiosis. In the same way, the superior research equipment at FMIPA UGM can be used by universities throughout the country or other agencies that need it. The obstacle encountered in updating and add new equipment lies in the very high price of the tool. For this reason, efforts have been made to obtain DIKTI funds and grants from abroad.

The availability of classrooms, laboratory rooms, lecturer rooms, and research rooms is relatively good. In 2012 the S2/S3 building, with a total building area of 3750 m2, was completed with community funds that cost around 21 billion. The main focus of this building is to facilitate masters and S3 laboratory rooms and equipment, as well as lecture halls for S1. Since August 2012, this building began to be used to support the lecture process for both S1, Masters, and Doctoral Study Programs within the FMIPA UGM. The five-story building is shared by the Department of Chemistry (1st floor), The Department of Physics (2nd floor), the Department of Mathematics (3rd floor), the Department of Computer Science and Electronics (4th floor), as well as joint facilities managed by the faculty (5th floor).

In order to meet national space standards, in 2015, an Integrated Lecture Building was built (Library, seminar room, lecture hall and office) covering an area of around 6000 m2 with a total fund of around 50 billion rupiahs sourced from the State Budget and was inaugurated on May 11, 2016 and has been used for lectures in the first semester of 2016/2017. In 2021, the Phase II Integrated Lecture Building was built with public funds of 63 billion rupiahs.

1.10 ACADEMIC QUALITY ASSURANCE

To ensure the implementation of education at FMIPA UGM to realize the Vision and Mission, Goals and Objectives that meet the quality standards that have been set, FMIPA carries out the following agenda:

1. Prepare long-term program planning for FMIPA UGM, which always refers to the Strategic Plan (RENSTRA) document 2003-2007 FMIPA UGM, RENSTRA 2008-2012, RENSTRA 2013-2017 and then continued to be RENSTRA 2018-2022, which has been completed with the ratification of the Faculty Senate. In its implementation, the items of the STRATEGIC PLAN are translated into the Operational Plan (RENOP) and annual programs in the form of the Annual Performance Plan (CTR) and the Annual Activity and Budget Plan (RKAT), along with the quality standards for the implementation of education as a reference for implementation.
2. Conduct monitoring and evaluation of the process of providing education. The monitoring mechanism for its implementation is carried out by the Management of Departments and study programs by establishing an Academic Activity Coordination Team (TK2A) at the department or study program level and a Semester Coordination Team (TKS) in the study program.

To ensure the implementation of the two things above, a Quality Assurance Unit has been formed based on the Rector's Decree No. 1619/P/SK/HT/2015. This UJM is responsible for implementing the faculty-level Internal Quality Assurance System (SPMI). SPMI is a systemic activity of quality assurance of education by the faculty to supervise the implementation of higher education by the faculty on an ongoing basis. Supervise means 'planning', 'implementation', 'control', and 'development/improvement' (PPEPP) of higher education quality standards as the university consistently and sustainably for stakeholder satisfaction.

This SPMI is carried out to achieve

(i) compliance with academic policies, academic standards, academic regulations, and academic quality manuals,

(ii) certainty that graduates have competencies following those set in each study program,

(iii) certainty that each student has a learning experience following the specifications of the study program, and

(iv) the relevance of education and research programs to the demands of the community and other stakeholders.

In this Internal Quality Assurance System (SPMI), UJM, together with KJM, periodically (annually) conduct internal audits of the Master's study program to evaluate, correct and at the same time improve on an ongoing basis. The implementation of SPMI as a form of continuous quality improvement at the study program level can be presented in the following scheme.

From the scheme above, it appears that the SPMI cycle at the faculty level can evaluate the implementation of education following quality standards and encourage the implementation of improving the quality of the Master's study program at FMIPA UGM sustainably.

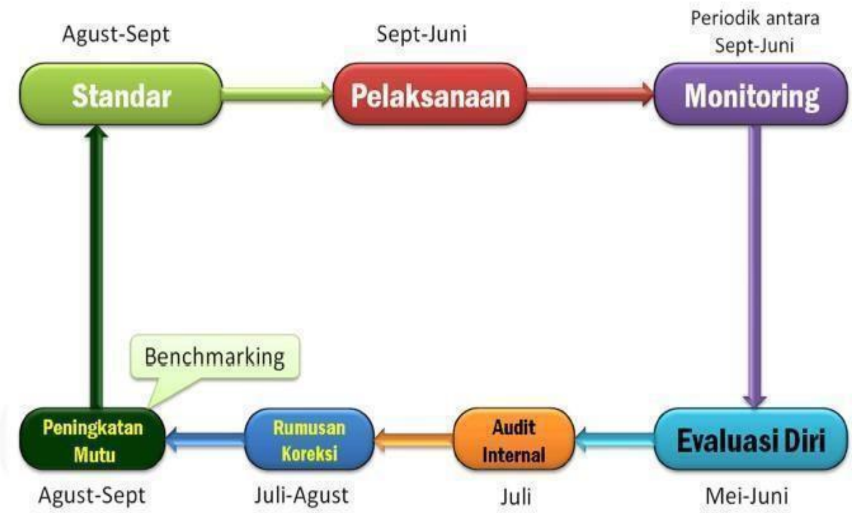

Figure 1.2 SPMI Implementation Scheme

1.11 TRANSITIONAL REGULATIONS

1. The 2022 curriculum of this Master's Program is applied to start in the first semester of the 2022/2023 academic year and applies to students of 2022/2023 and the class after that. Students of the previous batch follow the transitional regulations in each study program.
2. All courses completed in the old curriculum; the grades of these courses are still recognized with credits attached to the course.
3. Matters not regulated in this transitional regulation will be accommodated or regulated at the UPPS level / respective study programs.

MASTER OF PHYSICS

BAB 3 PHYSICS DEPARTMENT

3.1 INTRODUCTION

Department of Physics FMIPA-UGM, previously known as Physics Major FMIPA-UGM, was established in 1955 with only a few teaching staff and students, then developed rapidly until the establishment of the Basic Physics Laboratory, Atomic and Nuclear Physics Laboratory, Material Physics and Instrumentation Laboratory, as well as the Laboratory of Vibration and Waves which later developed into the Geophysics Laboratory. In addition to laboratories, the physics department has workshops as supporting facilities, including Mechanical Workshop, Glass Workshop, Photography Workshop, and Instrumentation Repair and Maintenance Workshop.

Currently, the Department of Physics FMIPA UGM organizes 4 major programs (known as program studi in Bahasa), namely the Undergraduate Physics Program, Undergraduate Geophysics Program, Masters Physics Program, and Doctorate Physics Program. The department of Physics has four laboratories consisting of Basic Physics Laboratory, Atomic and Nuclear Physics Laboratory, Materials Physics and Instrumentation Laboratory, and Geophysics Laboratory. The lecturers at the Physics Department are grouped into four groups of areas of expertise (abbreviated as KBK); KBK Theoretical and Computational Physics, KBK Functional Materials Physics, KBK Applied Physics, and KBK Geoscience.

3.2 VISION

In 2037 became a nationally superior and internationally leading department that developed physics and Geophysics for the welfare of the nation imbued with the nation's cultural values based on Pancasila.

3.3 MISSION

The mission of the Department of Physics, Faculty of Mathematics and Natural Sciences UGM is to:

1. The mission of the Department of Physics, Faculty of Mathematics and Natural Sciences UGM is to:Develop international education in physics and geophysics by utilizing the most research results.
2. Conduct excellent, innovative, and targeted research in the field of physics and geophysics for the welfare of the nation in particular and humanity in general.
3. Carry out community service by utilizing the most research results in the field of physics and geophysics to solve the problems of the nation and mankind.
4. Develop sustainable resources, organization and governance, and supporting facilities.

3.4 PURPOSES

The object to be achieved is the realization of the Department of Physics as part of FMIPA UGM to become an excellent department in Indonesia with international achievements and reputation through:

1. Education in physics and geophysics as an international standard education that is charged cross-disciplinary, innovative, soft skills, and supported by cutting-edge information technology with postgraduate programs as backbone in producing graduates who are healthy, virtuous, confident, competitive, innovative and entrepreneurial, and responsible for the nation.
2. Research in the field of physics and geophysics are excellent, innovative and targeted, which can become a national and international reference, and can provide solutions to human problems, based on the superiority of human and natural resources as well as local wisdom by involving stakeholders.
3. Excellent and innovative community service based on appropriate science and technology in the fields of physics and geophysics, which is able to encourage self-reliance and sustainable community welfare, by making the campus a means of implementing science and technology innovation for the community, and implementing a product development management system to support research results.
4. Development of equitable, transparent, participatory, and accountable Resources, Organization and Governance to support the effectiveness and efficiency of resource utilization, based on integrated information technology systems to support the implementation of adaptive learning processes to Industry 4.0.

3.5 ACADEMIC STAFF

The Department of Physics FMIPA UGM currently has 52 (fifty-two) lecturer staff with 42 of them having doctoral education, and 7 of them have reached the position of Professor. The following is a list of permanent teaching staff of the Department of Physics

KBK Theoretical and Computational Physics

Associate Professor

Dr. Arief Hermanto, Drs., S.U., M.Sc.
Drs. Pekik Nurwantoro, M.S., Ph.D.
Dr.rer.nat. Muhammad Farchani Rosyid, M.Si.
Dr.Eng. Rinto Anugraha NQZ, S.Si., M.Si.
Dr.Eng. Fahrudin Nugroho, S.Si., M.Si.
Sholihun, S.Si., M.Sc., Ph.D.

Assistant Professor

Dr. Eko Sulistya, M.Si.
Dwi Satya Palupi, S.Si., M.Si.
Mirza Satriawan, S.Si., M.Si., Ph.D.

Dr. Iman Santoso, S.Si., M.Sc.
Romy Hanang Setya Budhi, S.Si., M.Sc., Ph.D.

Expert Assistant
Dra. Eko Tri Sulistyani, M.Sc.

Teaching Staff
Elida Lailiya Istiqomah, S.Si., M.Sc.
Idham Syah Alam, S.Si., M.Sc., Ph.D.
Chalis Setyadi, S.Si., M.Sc.

KBK Functional Materials Physics

Professor
Prof. Dr. Harsojo, S.U., M.Sc.
Prof. Dr. Eng. Kuwat Triyana, M.Si.
Prof. Yusril Yusuf, S.Si., M.Si., M.Eng., Ph.D.

Associate Professor
Dr.Eng. Edi Suharyadi, S.Si., M.Eng.
Dr. Juliasih Partini, S.Si., M.Si.
Moh. Adhib Ulil Absor, S.Si., M.Sc., Ph.D.

Assistant Professor
Dr. Chotimah, M.S.
Dr.Sc. Ari Dwi Nugraheni, S.Si., M.Si.
Dr.Eng. Ahmad Kusumaatmaja, S.Si., M.Sc.

Expert Assistant
Ibn Jihad, S.Si., M.Sc.

Teaching Staff
Muhamad Darwis Umar, S.Si., M.Si., D.Sc.
Dr. Muhammad Arifin, S.Si., M.Sc.
Devy Pramudyah Wardani, S.Si., M.Sc.

KBK Applied Physics

Professor
Prof. Dr. Karyono, S.U.
Prof. Dr. Agung Bambang Setio Utomo, S.U.
Prof. Drs. Gede Bayu Suparta, M.S., Ph.D.

Associate Professor
Drs. Wagini R., M.S.
Drs. Sunarta, M.S.

Dr. Moh. Ali Joko Wasono, M.S.
Dr. Bambang Murdaka Eka Jati, MS.
Dr. Mitrayana, S.Si., M.Si.

Assistant Professor
Ikhsan Setiawan, S.Si., M.Si.

KBK Geosciences

Professor
Prof. Dr. Sismanto, M.Si.

Associate Professor
Dr. Wahyudi, M.S.

Assistant Professor
Drs. Imam Suyanto, M.Si.
Dr. Budi Eka Nurcahya, M.Si.
Dr.rer.nat. Wiwit Suryanto, S.Si., M.Si.
Dr.rer.nat. Mochamad Nukman, S.T., M.Sc.
Dr. Ing. Ari Setiawan, M.Si.
Dr. Sudarmaji, S.Si, M.Si.
Dr. Eddy Hartantyo, M.Si.
Dr. Afif Rakhman, S.Si., M.T.
Dr. rer. Nat. Herlan Darmawan, M.Sc.

Expert Assistant
Dr.rer.nat. Sintia Windhi Niasari, M.Eng.

Teaching Staff
Dr.rer.nat. Ade Anggraini, S.Si., M.Si.
Dr. Theodosius Marwan Irnaka, S.Si., M.Sc.
Adam Sukma Putra, S.Si., M.Si.

3.6 OBJECTIVE AND ACHIEVEMENT STRATEGIES

The objectives and strategies to achieve the goals of the Department of Physics FMIPA UGM are as follows:

Goals and Achievement Strategies for Objective 1

International standard education that contains cross-disciplinary, innovative, soft skills, and is supported by the latest information technology with postgraduate programs as the backbone in producing graduates who are healthy, virtuous, confident, competitive, innovative and entrepreneurial, and responsible for their nation.

1. Improve the quality of the new student admission system based on academic ability, diversity, independence, and inclusion.
2. Create and improve the culture of quality education and learning processes.
3. Develop cross-disciplinary education and learning and exposure to global competencies.
4. Create postgraduate education the backbone of the Tridharma Perguruan Tinggi.
5. Internationalization of study programs.
6. Improve the spirit of innovation and social entrepreneurship of students.
7. Improve the healthy lifestyle of students.

Goals and Achievement Strategies for Objective 2

Excellent, innovative, and focused research, which can become a national and international reference, and can provide solutions to the problems of the nation and mankind, based on the superiority of human and natural resources as well as local wisdom by involving stakeholders.

1. Develop multidisciplinary research with environmental insights and local values of excellence to provide solutions to problems of society, nation, and state.
2. Develop innovative research based on cultural wisdom that has a strong impact on the development of science and technology for the benefit of the nation, state, and humanity.
3. Improve research funding capabilities by involving external stakeholders.
4. Increase research institutions and capacity of research facilities and laboratories.

Goals and Achievement Strategies for Objective 3

Excellent and innovative community service based on expertise, science, and appropriate technology in the fields of physics and geophysics, which is able to encourage self-reliance and sustainable community welfare, by making the campus a means of implementing science and technology innovation for the community and implementing a product development management system to support research results.

1. Become a strategic partner of the government to increase productivity and welfare based on community driven.
2. Develop the Department of Physics as a means of implementing science and technology for the wider community.
3. Improve the reach and quality of community service through the development of entrepreneurship and social awareness.
4. Build synergy with alumni networks in the regions to strengthen access to

community service.

5. Increase the role of the Department of Physics as a spring of inspiration for community service.

Goals and Achievement Strategies for Objective 4

Development of Resources, Organization, Cooperation, and Governance that is equitable, transparent, participatory, and accountable to support the effectiveness and efficiency of resource utilization, based on an integrated information technology system to support the implementation of an adaptive education and research process to Industry 4.0.

1. Develop a human resources admission system.
2. Develop an employee career system.
3. Health-promoting department.
4. Improve integration in the management and utilization of facilities for service optimization.
5. Increase strategic cooperation to accelerate the development of education, research results, and scientific, technological, and cultural innovations.
6. Improve synergism and the contribution of alumni in strengthening the Tridharma Perguruan Tinggi.
7. Develop programs to facilitate the creativity and synergy of research results that are continued in the process of rotation or incubation.
8. Strengthening the culture of service and superior performance through strengthening bureaucratic reforms.
9. Reinforce institutions to achieve international level departments.

3.7 FACILITIES AND INFRASTRUCTURE

The Department of Physics has:

1. All lecture rooms and courtrooms are equipped with air conditioning and LCD projectors and WiFi facilities.

2. All hallways in the Physics Building and 2nd floor of the Postgraduate Building are equipped with CCTV.

3. Each Lecturer Room, Courtroom, Master and Doctoral Student Workspace is equipped with a computer connected to the internet network and WiFi facilities.

4. Lab equipment in the Atomic and Core Physics Laboratory in the form of: Digital / Analog Multimeter (AVO METER); Digital/Analog Thermometer; Surveymeter; Dosimeter; Binocular Microscope; Sound level meter; LCR Meter; Gauss Meter; Tesla Meter; Oscilloscope; Electrical Photo Effect Equipment unit; Apparatus Property; Microwave Gun Diode (Microwave) unit; Michelson interferometer; TAR (Thermo Acoustic Refrigeration) unit; e/m Thomshon units; Frank Hertz unit; Electron Spin Resonance (ESR) units ; Atomic Spectroscopy unit; Zeeman effect unit; Wavelength Meter unit; XRD Apparatus (for practice) unit; GM

Counter unit; Spectroscopy of alpha units; Beta Spectroscopy unit; Spectroscopy Gamma unit; X-ray Spectroscopy units; Microwave Klystron unit; Raman Spectroscopy unit; Spectrometer Photo Luminance Unit ; UV-VIS spectrometer; Spin Coater; UTM (Unit Tension Machine); Photoacoustic Laser unit; Digital Radiography (CT Scan) unit; Digital Radiography unit; Tomography of the unit; Thermoacoustic unit ; Ellipsometry unit; Ray Safe X2 Prestige; Ultrasound Units And Tomography; Jetson Xavier; jupyterhub server ; Rotary vacuum with oil trap; and Acoustic Absorption Coefficient.

5. The list of Materials Physics Laboratory equipment includes Transistor-Kit; Op Amplifier Kit; Gate Logic Kit; Seven Segment Kits; DC Circuit Current Kit; Arduino Kit; Hall effect Kit; Dielectric Kit; Solar Cell Kit; Gap Energy Measurement Kit (bulk); Gap Energy Measurement Kit on LEDs; Magnetic Susceptibility Test Kit; Computers for computing; Keithley IV Meter; UV Vis spectrometer; Surface Plasmon Resonance (SPR); Quartz Micro Balance Kit (QCM); E-Nose Kit; E-Tongue Kit; Electro Spinner; Spin Coater; Centrifuge; Stirrer/Hot Plate; Digital scales; Microwave Oven; Furnace; Microscope; Waterbath; Gausmater; pH meter; conductivity meter; Digital Multimeter; Analog Multimeter.
6. The list of main equipment of Geophysical Laboratory includes: Gravity Method Survey Tool: Lacoste Gravity meter & Romberg Model G, Magnetic Method Survey Tool: PPM Geotron G5, Fluxgate Magnetometer FGM3D/100, AF Demagnetizer LDA5; Electromagnetic Method Survey Tool: StrataGem EH-4 Magnetotelluric System, T-VLF System IRIS; Electrical Resistivity Method Survey Tool: OYO McOHM Mark-2 Resistivity Meter, ARES Resistivity & IP System, Naniura NRD-300 Resistivity Meter; Seismic Method Survey Tool: 24 Channels Seismograph DoReMi, Broadband Seismometer Guralp CMG-3T (Monitoring Volcano Merapi), SP Seismometer Lennartz LE-3D/20s, SP Seismometer Lennartz LE-3D/DIN, Seismometer Kinemetrics Ranger SS-1; Geological Survey Equipment: Compass and Geological Hammer, SUUNTO Clinometer etc.; Position Survey Tools: GPS Geodetic Altus APS-3, GPS Mobile Mapper, GPS Geodetic Trimble 4600 SE, Handheld GPS Garmin, Theodolite Manual Topcon; Portable Drone System DJI Mavic Pro; Multipurpose Data Logger, Oscilloscope, Automatic Function Generator, Digital Sound Level Meter, Thermal Sensor; Parallel Computer Devices for Geophysical Computing and Modeling; Field Communication Support Devices; Field Vehicles.

The Department of Physics occupies:

1. Physics Building with an area of 8100 m2 for the Secretariat Room of Departments and Study Programs, Seminar Room, Laboratory, postgraduate student Workspace, and Lecturer Room.
2. One floor in the postgraduate Building with an area of 4480 m2 for the Master's Study Program lecture hall, seminar room, master and doctoral study program student workspace.
3. FMIPA Lecture Building on the 3rd floor will be used by the Physics department for the development of research and innovation in the Physics department with an area of 782 m2.

3.8 QUALITY ASSURANCE

The internal Quality Assurance System (abbreviated as SPMI in Bahasa) in the Physics Department follows the quality assurance system at the Faculty level. SPMI at the Department level is implemented by the formation of a Semester Coordination Team (abbreviated as TKS in Bahasa) whose members consist of representatives of lecturers, laboratories, and students of each batch. The TKS meeting is scheduled at least once a semester.

3.9 MASTER OF PHYSICS STUDY PROGRAM

A Introduction

Master of Physics Study Program was originally named Master of Science Physics Study Program, officially established based on the Decree of Direktorat Jenderal Pendidikan Tinggi, Departemen Pendidikan dan Kebudayaan, Republik Indonesia, with Decree number no: 580/Dikti/Kep/1993 dated September 29, 1993, under the name the master's degree program in Physics. The decree was updated with SK Dirjen Dikti no 153/DIKTI/Kep/2007 dated 21 September 2007, with the same study program name. Due to the decree of Rektor UGM No. 526/P/SK/HT/2008, about Restructuring and Re-assignment of the Permits to Organize Study Programs at Gadjah Mada University, dated November 24, 2008, the Master of Science Physics Study Program name was changed to Master of Physics Study Program.

B Vision

In 2037, becoming a Master of Physics Program that excels in various academic aspects, and produces graduates who are competent and qualified and can be proud of at the national level and recognized at the international level.

C Mission

The mission of the Master of Physics Program, Faculty of Mathematics and Natural Sciences UGM are:

1. Organizing a quality learning process in various fields of Physics that can provide a deep understanding of Physics for the study of the branches of Advanced Physics.
2. Organizing quality learning processes in various fields of Advanced Physics that can prepare students to conduct Physics research independently.
3. Organizing a process of guidance and assistance in research to prepare students to be able to carry out quality Physics research activities.

D Program Objective

Producing postgraduates who have the following competencies:

1. Mastering various fields of Physics studies that allow him/her to expand and/or deepen a field of advanced physics studies.
2. Mastering in depth one of the disciplines of Physics so as to be able to produce innovative and tested work.
3. Able to solve complex problems in physics through a multidisciplinary approach.
4. Able to plan and manage research properly so that it can produce research works that have the potential to be applied and are worthy of publication in reputable scientific journals at the national or international level.

E Curriculum Targets

For the period 2022-2027, the targets in order to realize the vision, mission, and objectives of the Master of Physics Study Program mentioned above are as follows:

1. The realization of research-based learning, both fundamental and applied. Research-based learning means that (a) learning content is always related to the development of research results or gives direction to the development of research in related fields, (b) students are involved in research carried out by lecturers. Such involvement is expected to be able to provide provisions and train students to be able to solve problems that will be faced in the real world in society and to prepare them to work as academics and researchers.

2. Increased international reputation in academics. International reputation in the field of education means international recognition of our graduates or the use of our study programs by the international community as an option in continuing education. International reputation can also be seen from the increasing international reputational publications produced by students and contribute to the development of existing research.

3. Increased international cooperation. The increase in international cooperation networks is very closely related to the improvement of international reputation, that is, mutual support for each other. The establishment of international cooperation can be seen as recognition of the international reputation of the institution and, conversely, the existence of international cooperation can enhance the international reputation.

F Basic Curriculum Preparation

The basis for the preparation and direction of curriculum change based on:

1. Law Number 12 of 2012 about Higher Education.
2. Decree of the Minister of Education and Culture Number 3 of 2020 about National Standards for Higher Education.
3. Presidential Regulation Number 8 of 2012 about Indonesian National Qualifications Framework (abbreviated as KKNI in Bahasa).
4. Regulation of Rector Universitas Gadjah Mada Number 14 of 2020 about Basic Framework for the Curriculum of the University of Gadjah Mada.
5. Regulation of Rector Universitas Gadjah Mada Number 18 of 2019 about Implementation of the Research-Based Postgraduate Program at Gadjah Mada University.
6. Regulation of Rector Universitas Gadjah Mada Number 11 of 2016 about Postgraduate Education.
7. Curriculum document of master's Program of FMIPA UGM in 2017.
8. Addendum to the curriculum document for the FMIPA UGM Master's Program in 2021 Based on Research.
9. Results of the Internal Quality Audit (abbreviated as AMI in Bahasa) during the period 2017 – 2021.
10. The results of the evaluation of the Semester Coordination Team (TKS) for the period 2017 - 2021.
11. The results of the tracer study and input from stakeholders (graduate users, Physical Society of Indonesia (abbreviated as PSI in Bahasa), industry, and others).

G Professions/Employment of Graduates

Based on the results of graduate tracking that has been carried out it is known to have professions in several fields as follows:

1. Educators, both lecturers in colleges and teachers in high schools,
2. Researchers, both researchers in government agencies, private sector, and independent researchers,
3. Consultant
4. Bureaucrats, and
5. Entrepreneur.

H Graduate Profile

Based on this profession, it is determined that the profile of graduates has three main profiles, namely:

1. Educators (lecturers and teachers),
2. Researchers
3. Consultants, Bureaucrats and Entrepreneurs.

The details of the description of each graduate profile are described below:

1. Educators (lecturers and teachers),
   Have a deep mastery of Physics, able to teach well, able to conduct research independently and able to present research results well and ready to continue studies to the doctorate level.
2. Researchers
   Have a deep mastery of Physics, able to conduct research independently and able to present research results well and ready to continue studies to the doctorate level.
3. Consultants, Bureaucrats and Entrepreneurs.
   Have a deep mastery of Physics, able to apply his scientific understanding in various problems in society related to Physics.

I Graduate Learning Outcomes

CPL 1. ATTITUDES AND ETHICS

Have a commendable attitude, and ethics as a scientist. These commendable attitudes and ethics include:

1. Be devoted to The Almighty God and be able to show a religious attitude.
2. Upholding human values in carrying out duties based on religion, morals, and ethics.
3. Contribute to improving the quality of life in society and the progress of civilization based on Pancasila value.
4. Acting as citizens who are proud and love the motherland, have nationalism and a sense of responsibility to the nation.
5. Respect the diversity of cultures, religions, and beliefs, as well as the original opinions or findings of others.
6. Work together and have social sensitivity and concern for the community and the environment.
7. Obey the law and discipline in social and state life.
8. Internalizing academic values, norms, and ethics.
9. Demonstrate an attitude of responsibility for work in their field of expertise independently.
10. Internalizing the spirit of independence, struggle, and entrepreneurship.

CPL 2. PROFESSIONALISM

Have the professional ability of a scientist. These professional abilities include:

1. Able to make decisions in the context of solving problems in the development of science and technology and apply humanities values

based on analytical or experimental studies of information and data.

2. Able to manage, develop and maintain networks with colleagues, peers within the institution and the wider research community.
3. Able to increase learning capacity independently.
4. Able to increase the capacity to work together in a teamwork or project work.
5. Can adapt to failures, and difficulties that arise unexpectedly in conducting research or development projects.
6. Able to carry out professional activities outside their field of specialization, using knowledge of physical sciences, scientific methods and problem solving strategies.

1. Mampu mengambil keputusan dalam konteks menyelesaikan masalah pengembangan ilmu pengetahuan dan teknologi yang memperhatikan dan menerapkan nilai humaniora berdasarkan kajian analisis atau eksperimental terhadap informasi dan data
2. Mampu mengelola, mengembangkan dan memelihara jaringan kerja dengan kolega, sejawat di dalam lembaga dan komunitas penelitian yang lebih luas;
3. Mampu meningkatkan kapasitas pembelajaran secara mandiri;
4. Mampu meningkatkan kapasitas bekerja sama dalam suatu kerja tim ataupun kerja proyek
5. Memiliki kemampuan beradaptasi terhadap kegagalan, dan kesulitan-kesulitan yang muncul tak terduga dalam melakukan penelitian atau proyek pengembangan.
6. Mampu melakukan aktivitas profesional di luar bidang spesialisasinya, dengan menggunakan pengetahuan ilmu fisika, metode ilmiah dan strategi penyelesaian masalah.

CPL 3. CUTTING-EDGE PHYSICS KNOWLEDGE

Further mastering the theoretical knowledge of classical and modern physics, and its association with other disciplines, and having mastered one area of advanced physics specialization that allows him to keep up with the latest international research developments.

CPL 4. MATHEMATICAL AND COMPUTATIONAL

Mastering various mathematical disciplines related to a field of advanced physics and being able to develop physical models using various mathematical and computational devices with an inter or multidisciplinary approach to solving problems related to an advanced field of physical science.

CPL 5. RESEARCH

Able to plan, manage and carry out experiments and conclude the results, or be able to create and use modeling and simulation based on basic physics rules to study and solve a problem in a scientific field of Physics or Applied Physics that produces tested and innovative models, methods, or theories.

CPL 6. APPLICATION AND PROBLEM SOLVING

Able to apply knowledge to analyze, synthesize, formulate problems, and solve problems comprehensively in one of fields of Advanced Physics, through experimental or theoretical research, then can classify and draw conclusions of their findings for the development of science and technology.

CPL 7. COMMUNICATION AND DISSEMINATION

Able to communicate and discuss orally and in writing the results of studies, and their mastery of various problems in the field of physical sciences and other related fields in Indonesian and English, as well as being able to document and store the results of these studies and masteries, as well as publish them in scientific forums or reputable scientific journals.

These communication skills include:

1. Able to develop logical, critical, systematic, and creative thinking through scientific research, the creation of designs or works of art in the fields of science and technology that can be applied to humanities values in accordance with their fields of expertise, compile scientific conceptions and study results based on scientific rules, procedures, and ethics in the form of a thesis or other equivalent forms, and uploaded on the college website, as well as papers that have been published in accredited scientific journals or accepted in international journals;
2. Able to compile ideas, thoughts, and scientific arguments responsibly and based on academic ethics, and communicate them through the media to academic community and wider community.
3. Able to document, store, secure, and rediscover research data in order to ensure validity and prevent plagiarism.

J Field / Study Material

Concerning the formulation of graduate profiles; Program Learning Outcomes (abbreviates as PLO) formulated above; as well as paying attention to recommendations and benchmarks with several similar study programs in several universities, it is determined that the field of study of the Master of Physics Study Program is as follows:

1. Electromagnetics
2. Atomic and Molecular Physics

3. Physics of Earth
4. Image Physics
5. Core and Particle Physics
6. Statistical Physics
7. Condensed Matter Physics
8. Exploration Geophysics
9. Environmental Geophysics
10. Geology
11. Gravity and Cosmology
12. Classical Mechanics
13. Quantum Mechanics
14. Computational Methods
15. Mathematical Methods
16. Measurement and Instrumentation Methods
17. Research Methods

K Course Map – Study Materials – PLO – Graduate Profile

Graduate learning outcomes (abbreviated as CPL in Bahasa) that will be attained for each graduate profile can be seen in Table 3.1. All graduate profiles have all graduate learning outcomes, but the intensity of a CPL varies between one graduate profile and another graduate profile.

Table 3.1. Graduate Profile Map and CPL

Graduate Learning Outcomes	Graduate Profile		
	Educators	Researchers	Consultants, Bureaucrats, & Entrepreneurs
CPL 1. Attitude and Ethics	Advanced	Advanced	Advanced
CPL 2. Professionalism	Advanced	Intermediate	Advanced
CPL 3. Advanced Physics Knowledge	Intermediate	Advanced	Intermediate
CPL 4. Mathematics & Computational	Advanced	Advanced	Intermediate
CPL 5. Research	Intermediate	Advanced	Intermediate
CPL 6. Applications & Troubleshooting	Intermediate	Advanced	Advanced
CPL 7. Communication and Dissemination	Advanced	Intermediate	Advanced

The field of study that has been prepared and determined by the Master of Physics study program is then described in more detail in various courses to support the realization of CPL. The grouping of courses into fields of study that have been determined in the Master of Physics Study program is given in Table 3.2.

Table 3.2. Map of Fields of Study and Courses

FIELD OF STUDY	CODE	COURSES	Cre dits
Electromagnetics	MFF 5411	Electrodynamics	3
	MFF 5412	Applied Electromagnetics	3
	MFF 5841	Microwave Theory and Applications	2
	MFF 5932	Potential Field Theory	3
Atomic and Molecular Physics	MFF 5321	Atomic and Molecular Spectroscopy	3
	MFF 5423	Laser Spectroscopy	2
	MFF 5424	Biomedical Optics	2
	MFF 5426	Laser Physics	2
	MFF 5434	Photoacoustic and Photothermal	2
Physics of Earth	MFF 5911	Physics of the Earth	3
	MFF 5916	Advanced Rock Physics	2
	MFF 5918	Vulcanology	2
Image Physics	MFF 5873	Digital Imaging	3
	MFF 5876	Imaging Methods in Physics	3
	MFF 5878	Image Reconstruction	3
	MFF 5811	Non-destructive Test	2
	MFF 5875	Three-Dimensional Imaging	2
	MFF 5880	Advanced Seismic Imaging	2
Core and Particle Physics	MFF 5114	Particle Physics	3
	MFF 5211	Nuclear Physics	3
	MFF 5281	Radiation Physics	3
	MFF 5872	Magnetic Resonance in Medical Physics	2
Statistical Physics	MFF 5051	Statistical Mechanics	3
	MFF 5056	Fractal and Chaos in Physics	2
Condensed Matter Physics	MFF 5601	Soft Condensed Matter Physics	3
	MFF 5611	Crystal Physics	3

FIELD OF STUDY	CODE	COURSES	Cre dits
	MFF 5617	Nanophysics	2
	MFF 5701	Condensed Matter Physics	3
	MFF 5710	Physics of Electronics Material	3
	MFF 5750	Condensed Matter Magnetism	3
	MFF 5780	Condensed Matter Optics	3
	MFF 5855	Spintronica	3
	MFF 5870	Biomaterial Physics	2
Exploration Geophysics	MFF 5881	Advanced Geothermal Exploration	2
	MFF 5070	Data Science for Geosciences	2
	MFF 5936	Mineral Exploration	2
	MFF 5937	Petroleum Exploration	2
	MFF 5939	Geoscience Field Camp	2
Environmental Geophysics	MFF 5891	Disaster Mitigation	2
	MFF 5924	Advanced Environmental Geophysics	2
	MFF 5915	Geoscience Frontiers	2
Geology	MFF 5910	Physical Geology	2
	MFF 5913	Geotechnical Engineering	2
Gravity and Cosmology	MFF 5041	General Theory of Relativity	3
	MFF 5951	Astrophysics	3
	MFF 5982	Cosmology	3
Classical Mechanics	MFF 5401	Classical Mechanics	3
	MFF 5404	Fluid Mechanics	3
	MFF 5431	Theoretical Acoustics	2
	MFF 5831	Advanced Continuum Mechanics	3
Quantum Mechanics	MFF 5033	Quantum Mechanics	3
	MFF 5034	Advanced Quantum Mechanics	3
	MFF 5115	Quantum Field Theory	3
Computational Methods	MFF 5010	Logic and Symbolic Computation in Physics	2

FIELD OF STUDY	CODE	COURSES	Cre dits
	MFF 5027	Computational Physics	3
	MFF 5032	Computation of Celestial Body Mechanics	2
	MFF 5039	Special Topics in Computational Physics	3
	MFF 5514	Condensed Matter Electronics Structure Computation	2
	MFF 5713	Material Design Computational	3
	MFF 5933	Geophysics Inversion	2
Mathematical Methods	MFF 5002	Special Topics in Theoretical and Mathematical Physics	3
	MFF 5003	Stochastics Process for Physicist	2
	MFF 5005	Group Theory for Physicist	2
	MFF 5007	Topology and Geometry for Physicist	2
	MFF 5009	Mathematical Physics	3
	MFF 5022	Functional Analysis for Physicist	2
Measurement and Instrumentation Methods	MFF 5052	Time Series Analysis	3
	MFF 5061	Methods of Experimental Physics	3
	MFF 5071	Physics of Instrumentation	3
	MFF 5073	Data Acquisition System	3
	MFF 5814	Material Characterization Methods	3
	MFF 5925	Analysis and Visualization of Geoscience Data	2
	MFF 5930	Advanced Seismology	3
	MFF 5931	Electromagnetic Survey	3
	MFF 5934	Non-Electromagnetics Survey	2
	MFF 5935	Quantitative Seismology	3
Research Methods	MFF 5001	Research Methodology	2
	MFF 6001	Thesis	8
	MFF 6011	Research I	3
	MFF 6012	Research II	3
	MFF 6013	Research III	3
	MFF 6021	National Seminar	3

BIDANG KAJIAN	KODE	MATA KULIAH	SKS
	MFF 6022	International Seminar	4
	MFF 6031	Scientific Publications A	4
	MFF 6032	Scientific Publications B	5

Table 3.3. Course Map and CPL

No.	Code	Courses	Credits	CPL1	CPL2	CPL3	CPL4	CPL5	CPL6	CPL7
1	MFF 5001	Research Methodology	2			5		5	5	5
2	MFF 5002	Special Topics in Theoretical and Mathematical Physics	3			4	5		5	
3	MFF 5003	Stochastics Process for Physicist	2			4	5		5	
4	MFF 5005	Group Theory for Physicist	2			4	5		5	
5	MFF 5007	Topology and Geometry for Physicist	2			4	5		5	
6	MFF 5009	Mathematical Physics	3			4	5		3	
7	MFF 5010	Logic and Symbolic Computation in Physics	2			4	3		4	
8	MFF 5022	Functional Analysis for Physicist Computational Physics	2			4	5		4	
9	MFF 5027	Computation of Celestial Body Mechanics	3			5	5		5	
10	MFF 5032	Komputasi Mekanika Benda Langit	2			4	5		5	
11	MFF 5033	Quantum Mechanics	3			5	5		4	
12	MFF 5034	Advanced Quantum Mechanics	3			5	5		4	
13	MFF 5039	Special Topics in Computational Physics	3			4	5		5	
14	MFF 5041	General Theory of Relativity	3			5	5		4	
15	MFF 5051	Statistical Mechanics	3			4	5		3	
16	MFF 5052	Time Series Analysis	3			4	4		4	
17	MFF 5056	Fractal and Chaos in Physics	2		3	4	5		5	

No.	Code	Courses	Credits	CPL1	CPL2	CPL3	CPL4	CPL5	CPL6	CPL7
18	MFF 5061	Methods of Experimental Physics	3	4		4	3	4	5	
19	MFF 5070	Data Science for Geosciences	2			4	4	3	4	3
20	MFF 5071	Physics of Instrumentation	3			5		5	5	
21	MFF 5925	Analysis and Visualization of Geoscience Data	2			4	3	3	4	3
22	MFF 5073	Data Acquisition System	3			4	3	4	5	
23	MFF 5114	Particle Physics	3			4	5		4	
24	MFF 5115	Quantum Field Theory	3			5	5		5	
25	MFF 5211	Nuclear Physics	3			4	4		4	
26	MFF 5281	Radiation Physics	3			4	4		5	
27	MFF 5321	Atomic and Molecular Spectroscopy	3			4	3		5	
28	MFF 5401	Classical Mechanics	3			5	4		3	
29	MFF 5404	Fluid Mechanics	3			5	5		5	
30	MFF 5411	Electrodynamics	3			5	4		3	
31	MFF 5412	Applied Electromagnetics	3			5	4		5	
32	MFF 5423	Laser Spectroscopy	2			4	3		4	
33	MFF 5424	Biomedical Optics	2		3	4	3		5	
34	MFF 5426	Laser Physics	2			4	3		4	
35	MFF 5431	Theoretical Acoustics	2			4	3		5	
36	MFF 5434	Photoacoustic and Photothermal	2			4	3		5	
37	MFF 5514	Condensed Matter Electronics Structure Computation	2			4	5		5	
38	MFF 5601	Soft Condensed Matter Physics	3			4	3		5	
39	MFF 5611	Crystal Physics	3			4	3		4	
40	MFF 5617	Nanophysics	2			5	3		5	

No.	Code	Courses	Credits	CPL1	CPL2	CPL3	CPL4	CPL5	CPL6	CPL7
41	MFF 5701	Condensed Matter Physics	3			5	3		4	
42	MFF 5710	Physics of Electronics Material	3			5		5	5	
43	MFF 5713	Material Design Computational	3			4	5		5	
44	MFF 5750	Condensed Matter Magnetism	3			4	3		5	
45	MFF 5780	Condensed Matter Optics	3			4	3		5	
46	MFF 5811	Non-Destructive Test	2		4	4	3	3	5	
47	MFF 5814	Advanced Continuum Mechanics	3	4		4	3		5	
48	MFF 5831	Microwave Theory and Applications	3			4	4		5	
49	MFF 5841	Spintronics	2			4	3		5	
50	MFF 5855	Biomaterial Physics	3			5	3		5	
51	MFF 5870	Magnetic Resonance in Medical Physics	2			4	3		5	
52	MFF 5872	Digital Imaging	2		3	4	3	3	5	
53	MFF 5873	Three Dimensional Imaging	3			4	3		5	
54	MFF 5875	Imaging Methods in Physics	2		4	4	4	3	5	
55	MFF 5876	Image Reconstruction	3		3	4	3		5	
56	MFF 5878	Microwave Theory and Applications	3		3	4	3		5	
57	MFF 5880	Advanced Seismic Imaging	2			4	4		3	
58	MFF 5881	Advanced Geothermal Exploration	2		3	4	3		4	
59	MFF 5891	Disaster Mitigation	2	5	5	4	3		5	
60	MFF 5910	Physical Geology	2	3	5	4	3		5	
61	MFF 5911	Physics of the Earth	3			4	3		4	
62	MFF 5913	Geotechnical Engineering	2			0			4	
63	MFF 5915	Geosciences Frontiers	2		3	5	3	3	5	

No.	Code	Courses	Credits	CPL1	CPL2	CPL3	CPL4	CPL5	CPL6	CPL7
64	MFF 5916	Advanced Rock Physics	2			5		3	3	
65	MFF 5918	Vulcanology	2			4	3		5	
66	MFF 5924	Advanced Environmental Geophysics	2	4		4	3		5	
67	MFF 5930	Advanced Seismology	3			4	3		5	
68	MFF 5931	Electromagnetic Survey	3			4	3	3	5	
69	MFF 5932	Potential Field Theory	3			4	3		5	
70	MFF 5933	Geophysics Inversion	2			4	3		5	
71	MFF 5934	Non-Electromagnetics Survey	2			4	3	3	5	
72	MFF 5935	Quantitative Seismology	3			3	5		3	
73	MFF 5936	Mineral Exploration	2		3	4	3		5	
74	MFF 5937	Petroleum Exploration	2			4	3		5	
75	MFF 5939	Geoscience Field Trip	2	3	5	4	3		5	
76	MFF 5951	Astrophysics	3			5	4		4	
77	MFF 5982	Cosmology	3			5	5		4	
78	MFF 6001	Thesis	8	3	3	5	4	5	5	5
79	MFF 6011	Research I	3		4	4	4	5	5	3
80	MFF 6012	Research II	3		4	4	4	5	5	3
81	MFF 6013	Research III	3		4	4	4	5	5	3
82	MFF 6021	National Seminar	3	4	5	4	3	4	4	5
83	MFF 6022	International Seminar	4	4	5	4	3	4	4	5
84	MFF 6031	Scientific Publications A	4	4	5	4	3	4	4	5
85	MFF 6032	Scientific Publications B	5	4	5	4	3	4	4	5

Description: Score 3 minimum – 5 maximum.

L List of Compulsory Courses (MKW)

Compulsory courses that apply to the Regular and Research-Based Physics Master's Program. The list of courses can be found in Table 3.4.

Table 3.4 List of Compulsory Courses

NO	CODE	COURSES	Cre dits	Semester
1	MFF 5001	Research Methodology	2	Odd/Even
2	MFF 6001	Thesis	8	Odd/Even
3	MFF 5009	Mathematical Physics	3	Odd/Even
4	MFF 5033	Quantum Mechanics	3	Odd/Even
5	MFF 5051	Statistical Mechanics	3	Odd/Even
6	MFF 5401	Classical Mechanics	3	Odd/Even
7	MFF 5411	Electrodynamics	3	Odd/Even

Students are required to take research methodology and thesis courses. Students are only required to pass three of the following five compulsory courses: Physics Mathematics, Classical Mechanics, Quantum Mechanics, Statistical Mechanics, and Electrodynamics.

M List of Elective Courses (MKP)

Elective courses that can be taken by students of the regular Physics Master's Program are grouped based on the KBK in the Department of Physics as follows:

ELECTIVE COURSE OF KBK MATERIAL PHYSICS

Table 3.5 List of Elective Courses KBK Material Physics

CODE	COURSES	Cre dits	Semester
MFF 5071	Physics of Instrumentation	3	Odd
MFF 5073	Data Acquisition System	3	Odd
MFF 5601	Soft Condensed Matter Physics	3	Odd
MFF 5611	Crystal Physics	3	Odd
MFF 5617	Nanophysics	2	Odd
MFF 5701	Condensed Matter Physics	3	Odd
MFF 5713	Material Design Computational	3	Odd
MFF 5855	Spintronics	3	Odd

CODE	COURSES	Cre dits	Semester
MFF 5412	Applied Electromagnetics	3	Even
MFF 5710	Physics of Electronics Material	3	Even
MFF 5750	Condensed Matter Magnetism	3	Even
MFF 5780	Condensed Matter Optics	3	Even
MFF 5814	Material Characterization Methods	3	Even
MFF 5870	Biomaterial Physics	2	Even

ELECTIVE COURSES KBK THEORETICAL AND COMPUTATIONAL PHYSICS

Tabel 3.6 List of Elective Courses KBK Theoretical and Computational Physics

CODE	COURSES	Cre dits	Semester
MFF 5003	Stochastics Process for Physicist	2	Odd
MFF 5005	Group Theory for Physicist	2	Odd
MFF 5007	Topology and Geometry for Physicist	2	Odd
MFF 5027	Computational Physics	3	Odd
MFF 5039	Special Topics in Computational Physics	3	Odd
MFF 5041	General Theory of Relativity	3	Odd
MFF 5115	Quantum Field Theory	3	Odd
MFF 5211	Nuclear Physics	3	Odd
MFF 5951	Astrophysics	3	Odd
MFF 5002	Special Topics in Theoretical and Mathematical Physics	3	Even
MFF 5010	Logic and Symbolic Computation in Physics	2	Even
MFF 5022	Functional Analysis for Physicist	2	Even
MFF 5032	Computation of Celestial Body Mechanics	2	Even
MFF 5034	Advanced Quantum Mechanics	3	Even
MFF 5056	Fractal and Chaos in Physics	2	Even
MFF 5114	Particle Physics	3	Even
MFF 5404	Fluid Mechanics	3	Even
MFF 5514	Condensed Matter Electronics Structure Computation	3	Even
MFF 5982	Cosmology	3	Even

ELECTIVE COURSES OF KBK APPLIED PHYSICS

Tabel 3.7 List of Elective Courses KBK Applied Physics

CODE	COURSES	Cre dits	Semester
MFF 5061	Methods of Experimental Physics	3	Odd
MFF 5281	Radiation Physics	3	Odd
MFF 5321	Atomic and Molecular Spectroscopy	2	Odd

CODE	COURSES	Cre dits	Semester
MFF 5431	Theoretical Acoustics	2	Odd
MFF 5841	Microwave Theory and Applications	2	Odd
MFF 5873	Digital Imaging	3	Odd
MFF 5811	Non-Destructive Test	2	Odd
MFF 5875	Three-Dimensional Imaging	2	Odd
MFF 5423	Laser Spectroscopy	2	Even
MFF 5424	Biomedical Optics	2	Even
MFF 5426	Laser Physics	2	Even
MFF 5434	Photoacoustic and Photothermal	2	Even
MFF 5872	Magnetic Resonance in Medical Physics	2	Even
MFF 5876	Imaging Methods in Physics	3	Even
MFF 5878	Image Reconstruction	3	Even

ELECTIVE COURSES OF KBK GEOSCIENCE

Tabel 3.8 List of Elective Courses KBK Geoscience

CODE	COURSES	Cre dits	Semester
MFF 5073	Data Acquisition System	3	Odd
MFF 5831	Advanced Continuum Mechanics	3	Odd
MFF 5881	Advanced Geothermal Exploration	2	Odd
MFF 5891	Disaster Mitigation	2	Odd
MFF 5911	Physics of Earth	3	Odd
MFF 5931	Electromagnetic Survey	3	Odd
MFF 5933	Geophysics Inversion	2	Odd
MFF 5935	Quantitative Seismology	3	Odd
MFF 5937	Petroleum Exploration	2	Odd
MFF 5939	Geoscience Field Trip	2	Odd
MFF 5913	Geotechnical Engineering	2	Odd
MFF 5915	Geoscience Frontiers	2	Odd
MFF 5925	Analysis and Visualization of Geoscience Data	2	Odd
MFF 5052	Time Series Analysis	3	Even
MFF 5910	Physical Geology	2	Even
MFF 5916	Advanced Rock Physics	2	Even
MFF 5918	Vulcanology	2	Even
MFF 5924	Advanced Environmental Geophysics	2	Even
MFF 5930	Advanced Seismology	3	Even
MFF 5932	Potential Field Theory	3	Even
MFF 5934	Non-Electromagnetics Survey	2	Even
MFF 5936	Mineral Exploration	2	Even

CODE	COURSES	Cre dits	Semester
MFF 5070	Data Science for Geosciences	2	Even
MFF 5880	Advanced Seismic Imaging	2	Even

Students of the Research-based Physics Master's Program can take elective courses in the list above (for regular programs) which are carried out classically, with the approval of the academic supervisor and the study program.

The elective courses that students of the Master of Physics by Research Program can take are as follows:

Tabel 3.8 List of Elective Courses master of physics by Research program

CODE	COURSES	Cre dits	Semester
MFF 6011	Research I	3	Odd/Even
MFF 6012	Research II	3	Odd/Even
MFF 6013	Research III	3	Odd/Even
MFF 6021	National Seminar	3	Odd/Even
MFF 6022	International Seminar	4	Odd/Even
MFF 6031	Scientific Publications A	4	Odd/Even
MFF 6032	Scientific Publications B	5	Odd/Even

The elective courses in Table 3.9 above are held in a non-classical manner. The elective courses in Table 3.9 above cannot be taken by students of the regular Master's Program.

N Transitional Regulations

1. Compulsory courses that appear in the 2022 curriculum are not required for old students (only required for the class of 2022 and beyond).
2. Compulsory courses and electives that have been taken by old students (class of 2021 and before) are still recognized.
3. The provisions of compulsory courses for the class of 2021 and previously followed the 2017 curriculum.

O Equivalence of Courses

1. Courses in the 2017 curriculum that have the same code and name as the courses in the 2022 curriculum are equivalent and are not shown in the Course Equality table in Table 3.10.

2. The courses of the 2017 and 2022 curricula that are in the Equality table in Table 3.10 are equivalent courses, and two equivalents should not be in the transcript for the judiciary.

3. Students who take two equivalent courses from two different curricula

must choose one of the courses that they will remove when applying for the judiciary.

Table 3.10 Course Equality Table

NO	CURRICULUM 2017			CURRICULUM 2022		
	CODE	COURSES	Cre dits	CODE	COURSES	Cre dits
1.	MFF 5711	Computational Methods of Materials Physics	3	MFF 5713	Material Design Computational	3
2.	MFF 5853	Spintronic Material	3	MFF 5855	Spintronics	3
3.	MFF 5923	Data Analysis and Visualization Methods	3	MFF 5925	Analysis and Visualization of Geoscience Data	2

P Student Input Requirements

To maintain the quality of student input for the Master of Physics study program, in addition to the requirements and selection at the University level as mentioned in the faculty section, there are additional requirements and selections at the study program level, which are:

1. To maintain Have a minimum English proficiency score of TOEFL 450 or AcEPT 209 (or equivalent).
2. For prospective research students (by Research): Candidates have received a recommendation and written approval of willingness to guide from prospective supervisors from the Department of Physics.

Q Learning Methods

Learning in the master's Physics UGM is carried out through classroom learning using the learning method recommended by the university, namely STAR - Student Teacher Aesthetic Role-sharing. This learning method is designed so that: (a) discussion forums and active communication between lecturers and students are formed; (b) facilities for improving skills and scientific insight; and (c) forum for developing inspiration and scientific ideas for students, in the implementation of lectures in class, practice in the laboratory and the field, and independent assignments.

For research-based students, most lectures are carried out in a non-classical manner, but a minimum of six credits (from compulsory courses) are carried out classically with a blended learning method. The implementation of compulsory course learning for research-based students is as follows:

1. Two credits of compulsory courses in Research Methodology are carried out non-classically by the thesis supervisor.
2. Two of the following five compulsory courses, namely: Physics

Mathematics, Classical Mechanics, Quantum Mechanics, Statistical Mechanics, and Electrodynamics, must be carried out in classically blended learning. The rest is carried out in a non-classical manner.

3. Classical lectures can be carried out through blended learning which is a learning method by combining face-to-face interaction without using a network and indirect face-to-face using information technology media by interacting in the network.
4. The determination of compulsory courses that are carried out classically blended learning and non-classically, is carried out during research-based prospective student eligibility meetings.

R Assessment Methods

Exams are one of the methods of student assessment when taking a course. Exams are held periodically, both scheduled and unscheduled, and may consist of Midterm Exams (abbreviated as UTS in Bahasa) and Final Exams (abbreviated as UAS in Bahasa). The midterm exam is held at least once a semester, either on a scheduled or unscheduled basis, while the Final Exam is held on a scheduled basis at the end of the semester. In addition to the two exams above, student assessment data can also come from various components such as assignments, questions and answers, quizzes, tests, and others during lectures. The final grade for a course is determined based on all the assessment data obtained from the various assessment activities above by giving a certain weight to each of the grade data.

If the student is unable to take the scheduled exam due to urgent circumstances, the student can request the holding of a follow-up / special exam. These urgent circumstances include being affected by natural disasters, becoming an ambassador of the nation/university/faculty, being sick (required letter recommendation from doctor/hospital), and rules for the Practice Work schedule on the provisions of the receiving Company that cannot be changed. Apart from these urgent circumstances, the study program will not hold officially scheduled follow-up exams, and the completeness of the assessment of these students are left entirely to the policy of the lecturer who teaches the course.

If the student has not passed a course or wants to improve the value of a course that has been taken, the student can repeat taking the course. There is no limit to the number of repetitions taken in a course, and the grade used for final graduation is the best score.

The final score in each course is expressed by a letter value corresponding to the following number values: A (4.0), A- (3.75), A / B (3.5), B + (3.25), B (3.0), B- (2.75), B / C 2.5), C + (2.25), C (2.5), C- (1.75), C / D (1.5), D + (1.25), D (1), and E (0). Completion of courses for master's programs is at least C.

Regulations regarding assessment methods that apply to regular programs and research-based programs. There are several additional assessment rules specifically for elective courses of research-based physics master's programs, as follows:

1. Assessment for Research I, II, and III courses is carried out through student presentations in monitoring seminars. The seminar presentation schedule for Research I, II, and III courses are in the middle of the semester (in the midterm exam period) and at the end of the semester (in the final exam period). Students who take Research I, II, and III courses can choose their presentations to be carried out in one of the two-time schedules that have been provided.
2. Monitoring seminars for Research I, II, and III was attended by academic supervisors/ thesis supervisors, relevant KBK representative lecturers, and study program administrators and could be attended by general students.
3. The assessment of courses in the monitoring seminars for Research I is carried out by a team of examiners appointed by the study program, consisting of academic supervisors/thesis supervisors and lecturers representing the relevant KBK.
4. The assessment of courses in the monitoring seminars for Research II and III is carried out by academic supervisors/thesis supervisors.
5. The assessment of National Seminars and International Seminars is carried out based on the completeness of national/international seminar requirements and presentation manuscripts in national/international seminars by academic supervisors/thesis supervisors.
6. The assessment of the Scientific Publication A course is carried out after the publication manuscript is complete and accepted for submission by the editor of the intended reputable international journal, with evidence submitted and will be processed for review. The assessment of the Scientific Publication A course is carried out based on the completeness of the requirements for a manuscript draft of international publications.
7. The assessment of the Scientific Publication B course is carried out after the publication manuscript is accepted for publication, with proof of acceptance for publication by a reputable international journal. The assessment of scientific publication course B is carried out based on the completeness of publication requirements in reputable international journals.

S Quality Assurance System

The quality assurance process is carried out following the Internal Quality Assurance System at the department, faculty, and university levels, which consists of five stages, which are Determination, Implementation, Evaluation, Control, and Improvement (abbreviated as PPEPP in Bahasa). The process is to ensure that there is a continuous improvement in the study program. At the study program level, the quality assurance system is entrusted to the Semester Coordination Team (abbreviated as TKS) which observes the learning process and is delivered at the coordination meeting of the Semester Coordination Team at the end of the semester, and the implementation of the Internal Quality Audit every year.

LAMPIRAN: SYLLABUS Mata Kuliah

COMPULSORY COURSES

MFF 5001 RESEARCH METHODOLOGY

MFF 5001 *Research Methodology*

(2 Credits of Compulsory Course Odd/Even Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this course, students are able to:

CO 1. Prepare thesis research proposals according to their interests.
CO 2. Analyze experimental data according to scientific rules.
CO 3. Explain and describe the process of making an international paper.

CO 4. Explain and describe the process related to IPR.

SYLLABUS

Introduction: the nature of science and research, the general framework of research as a scientific process which includes the definition of scientific research, the scientific method, and the research benefits. The rational model of the research process. Research design: research type, research substance, topic selection, implementation plan, problem formulation, research method, financing plan design. Research proposal: basic research and applied research, purpose and structure of the proposal, general guidelines for proposal preparation. Presentation, research report writing, and research publications include writing style and scientific article writing. Overview of IPR (Intellectual Property Rights) and its scope.

REFERENCES

1. Stock, M., 1985, *A Practical Guide to Graduate Research*, McGraw-Hill Book Co., New, York, USA.
2. Sukandarrumidi, 2002, Metodologi Penelitian, Petunjuk Praktis untuk Peneliti Pemula, Gadjah Mada University Press, Yogyakarta.
3. Suryabrata, S., 2003, Metodologi Penelitian, ed.2 Cet.15, PT Raja Grafindo Persada, Jakarta.

MFF 5009 MATHEMATICAL PHYSICS

MFF 5009 Physical Mathematics

(3 Credits of Compulsory Course Odd / Even Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this course, students are able to:

CO 1. Calculating vector addition and subtraction calculations, vector multiplication, look for vectors that are perpendicular to each other, express vectors in component form, create vector rotations and rotation matrices. Distinguish between true vectors and pseudo vectors. Calculates the derivative of a vector in a given direction, looking for a vector that is perpendicular to the isoscalar plane.

CO 2. Calculating line integrals, area integrals and volume integrals, converting area integrals to line integrals and vice versa, converting volume integrals to area integrals and vice versa. Looking for the application of line integral, area integral and volume integral in Physics.

CO 3. Perform transformations between curvilinear coordinates and provide examples of curvilinear coordinates and their covariance and contra-variant bases. Calculates derivatives and integrals of vectors on curved coordinates.

CO 4. Understand the concept of vector space and be able to construct vector space structures, both real and complex vector spaces. Mastering the concept of vector subspace and able to characterize vector subspace. Mastering the concepts of linear combinations, finite linear combinations, and linear stretches. Determine that a set of vectors is a linearly independent set or a linearly dependent set. Mastering the concept and able to determine the finite basis and infinite basis, the dimensions of the vector space, and the properties of the basis. Understand concepts and be able to define linear mapping, linear mapping kernel, linear mapping matrix expression, and basis transformation. Mastering and able to find solutions to systems of linear equations and self-assessment problems.

CO 5. Performing the characterization of partial differential equations, boundary conditions, and initial conditions. Calculating the solution of boundary conditions problems related to wave equations, heat propagation equations, and diffusion through various methods: Green function method, and self-function method.

SYLLABUS

Overview of basic vector concepts: vector algebra, unit vector, scalar multiplication, cross product, position vector, unit vector in Cartesian coordinates, vector components, vectors relative to the coordinate axis, rotation vectors, and rotation matrix.

Advanced vector constraints: true vectors and pseudovectors, examples of true vectors and pseudovectors.

Vector calculus: parameterized vectors, field definition, vector fields, scalar fields, isoscalar surfaces, vector derivatives, gradients and their meanings, divergences and their meanings, rotations and their meanings, essential identities, path integrals, surface integrals, space integrals, Gauss's theorem for vector fields, Gauss's theorem for scalar fields, Stokes' theorem for vector fields, Stokes' theorem for scalar fields, Green's theorem, continuous vector fields and potential concepts, solenoid vector fields, applied Gauss's theorem and Stokes' theorem.

Curved coordinate system: curvilinear coordinate system, coordinate domain, orthogonal coordinate system, coordinate transformation, examples, curvilinear coordinates, surface coordinates, covariance basis, contravariance basis, scale factor, line elements in curvilinear coordinates, area elements in curvilinear coordinates, volume element coordinates curved, vector calculus in curved coordinates.

Linear Algebra: vector spaces, real vector spaces, complex vector spaces, vector subspaces, characterization of vector subspaces, linear combinations, finite linear combinations, linear expanse, linear independent sets and linear dependent sets, finite and infinite bases, vector space dimensions, basic properties, linear mapping, linear mapping kernels, linear mapping matrix, basis transformation, linear equation system, eigenvalue problem.

Partial differential equations: characterization of partial differential equations, methods of solving partial differential equations, boundary conditions and initial conditions, solving boundary condition problems, wave equations, heat propagation and diffusion equations, Green functions, self-value problems, Hermitian differential operators, boundary condition problem-solving.

REFERENCE

K. F. Riley, M. P. Hobson, and S. J. Bence, 2006, *Mathematical methods for physics and engineering*, Cambridge University Press, Cambridge

MFF 5033 QUANTUM MECHANICS

MFF 5033 *Quantum Mechanics*

(3 Credits of Compulsory Course Odd/Even Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this course, students are able to:

CO 1. Formulate and describe the studied physical phenomena, and reveal important information in physics problems through various tricks or specific mathematical procedures with multiple approaches (estimates).

CO 2. Apply various forms of visualization, graphics, or simulations. For example, it is easier to understand the studied physics problem through computer assistance compared to the understanding through abstraction of mathematical expressions.

CO 3. Look for physics problems from various sources and references to understand important information

SYLLABUS

Understanding the experimental aspects and mathematical structures of quantum mechanics and their application to various atomic/nuclear phenomena include the principles and various formulations of quantum mechanics, operators, the implementations and their properties, one-dimensional and three-dimensional potential spherical symmetry, rotational angles of momentum. Identical particle systems and the Pauli principle, scattering and perturbation theory, and their implementation.

REFERENCES

1. Sakurai, J.J., 1985, Modern Quantum Mechanics, Benjamin Cummings.
2. Tannoudji, C.H., et al, 1977, Quantum Mechanics Vol.I & II., John Willey.

MFF 5401 CLASSICAL MECHANICS

MFF 5401 *Classical Mechanics*

(3 Credits of Compulsory Course Odd / Even Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this course, students are able to:

CO 1. Describes and discusses: Fundamentals of Mechanics, Newtonian Mechanics for single-particle and plural-particle systems, and calculus of variations to solve mechanical problems in Lagrangian formalism.

CO 2. Describe and discuss: The concept of symmetry and symmetry breaking and their relation to the preservation of a physical quantity through the Noether theorem. Lagrange's equation for a system having a central potential, i.e., planetary orbits and particle scattering.

CO 3. Describe and discuss: Hamiltonian formulation in solving mechanical system problems. The use of Euler-Lagrange formalism for kinematic motion of rigid bodies, Euler angles, rotation of rigid bodies (moment of inertia tensor), Euler equations, and apparent force effects (Coriolis).

CO 4. Explain and discuss: The use of Euler-Lagrange formalism for small oscillatory motions (sign damping, with damping, and external force). Canonical transformation and its relation to Euler Lagrange formalism and Hamiltonian formalism.

CO 5. Explain and discuss: Hamiltonian-Jacobi formalism in discussing the motion of objects. Special relativity theory and its relation to Lagrangian formalism and Hamiltonian formalism.

SYLLABUS

Fundamental Principles of Newtonian Mechanics, Lagrange, and Hamilton. A system with constraints, symmetry, and the law of conservation. Two-body systems, Kepler motion, kinetics, and rigid-body dynamics. Canonical variables and transformations, Poisson equations of motion, Hamilton-Jacobi theory, relativistic dynamics, swings, and their normal variances.

REFERENCES

1. Symon, K.R., 1971, Mechanics, edisi 3, Addison-Wesley.
2. Goldstein, H., 1980, Classical Mechanics, edisi 2, Addison-Wesley.

MFF 5411 ELECTRODYNAMICS

MFF 5411 *Electrodynamics*

(3 Credits of Compulsory Course Odd / Even Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this course, students are able to:

CO 1. Explain, calculate and analyze the magnetic field generated by the current distribution and changes in the electric field flux.

CO 2. Explain and formulate the magnetic field generated by the following electric multipole distribution.

CO 3. Formulate, explain the use of Maxwell's equations, and express Maxwell's equations in the form of electric potential and vector potential, as well as the propagation of electromagnetic waves.

CO 4. Explain and solve static electricity problems and their boundary conditions.

CO 5. Explain and calculate electric fields and electric potentials caused by electric multipole distributions.

SYLLABUS

Coulomb's law, electric field and potential caused by electric charge. Gauss's law for electricity and the density of electrical energy in a vacuum, Green's Theorem. Electrostatic potential energy, configuration energy, energy density. Boundary condition problems include solving boundary condition problems using the shadow method if there is a source. Solve Laplace's equations and Poisson's equations with specific boundary conditions. Multipole moment, electric field, and electric potential are generated by a multipole moment in a vacuum and a medium. The induced magnetic field is generated by current density distribution, Biot-Savart's Law, and Ampere's Law. Faraday's law and induced EMF, vector potential, differential equations in vector potential form, and how to solve them. Magnetic moments and magnetic induced fields are generated by magnetic moments in a vacuum and a linear isotropic medium. The magnetic field at the boundary plane. Maxwell's equations in differential, integral, scalar potentials and vector potentials form, tera transformations. A simple application of Maxwell's equations: electromagnetic waves.

REFERENCES

Jackson, J. D, 1999, Classical Electrodynamics, edisi3, John Wiley & Sons.

MFF 5051 STATISTICAL MECHANICS

MFF 5051 *Statistical Mechanics*

(3 Credits of Compulsory
Course Odd Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this course, students are able to:

CO 1. Understand the concept of thermodynamics.
CO 2. Understand the Concept of Phase Space.
CO 3. Understand Various Statistical Mechanics Ensembles.
CO 4. Understand the Concept of Quantum Statistics.
CO 5. Understand the Simple Application of Quantum Statistics.

SYLLABUS

Basic statistical concepts, Binomial distribution, Maxwell-Boltzmann distribution, laws of thermodynamics, statistical calculations of thermodynamic quantities, fluctuations, phase spaces, partition functions, and their properties, microcanonical ensembles, canonical and microcanonical, equipartition theorem, Liouville's theorem, classical statistical constraints with quantum, Bose-Einstein statistics, Fermi-Dirac statistics, free electron theory of metals, kinetic theory of transport processes, Boltzmann transport equations, phase changes (classical and quantum).

REFERENCES

1. W. Greiner, L. Neise, dan H. Stoecker, 1995, Thermodynamics and Statistical Mechanics, Springer.
2. K. Huang,1987, Statistical Mechanics, John Wiley and Sons.
3. Kittel, C dan Kroemer, H., 1980, Thermal Physics, McGraw-Hill.
4. Reif, F., 1965, Fundamentals of Statistical and Thermal Physics, W.H. Freeman & Co.

MFF 6001 THESIS

MFF 6001 Thesis

(8 Credits of Compulsory Course Odd / Even Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this course, students are able to:

CO 1. Formulate problems to be researched, make research boundaries, and set research objectives.
CO 2. Can formulate problems to be researched, make research boundaries, and set research objectives.
CO 3. Can conduct literature searches and compile literature reviews related to research problems to be studied.
CO 4. Can make research designs and determine appropriate research methods related to the problems to be studied.

CO 5. Can perform analysis and conclusions on the results of their research.

SYLLABUS

Independent research in a particular field of physics ends with writing a thesis as the final project of the master's program. This thesis is expected to contain an element of authenticity in how students formulate, handle and solve research problems. The thesis assessment is based on the quality of the thesis and the student's performance when presenting the thesis in the examination session. The aspects of the assessment are: (a) the quality of the thesis which includes the material, methodology, systematics of writing and language, and (b) the performance of the exam time which includes the expertise in the material and the methodology. Note: The final thesis score consists of 80% thesis test scores and 20% thesis proposal test scores.

ELECTIVE COURSES
KBK THEORETICAL AND COMPUTATIONAL PHYSICS

MFF 5002 SPECIAL TOPICS IN THEORETICAL AND MATHEMATICAL PHYSICS

MFF 5002 *Special Topics in Theoretical and Mathematical Physics*

(3 Credits of Elective Course Even Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this course, students are able to:

CO 1. Master the basic fields of physics, which include studies of Electrodynamics, Classical Mechanics, and Quantum Mechanics.

CO 2. Master and apply one of the fields of Advanced Physics.

CO 3. Master the ability to study a problem in a field of Physics through research.

CO 4. Master various mathematical disciplines relevant to the field of Advanced Physics.

CO 5. Master the basic fields of physics, which include studies of Electrodynamics, Classical Mechanics, and Quantum Mechanics.

SYLLABUS

It consists of specialized topics in particle physics, astrophysics, cosmology, econophysics, mathematical physics, gravity, etc.

REFERENCES

Depends on the topic.

MFF 5003 STOCHASTIC PROCESS FOR PHYSICIST

MFF 5003 *Stochastics Process for Physicist*

(2 Credits of Elective Course Odd Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this course, students are able to:

- CO 1. Explaining the properties of stochastic processes, forming stochastic differential equations and stochastic integrals for a physical system that follows a stochastic process.
- CO 2. Explain the use of physical stochastic processes.
- CO 3. State and explain the simple limitations of stochastic processes.
- CO 4. Explaining the basics of probability theory then mentioning examples of its application in physics and being able to explain the nature of the Lebesque integral then being able to solve the Lebesque integral for any measurable function

SYLLABUS

Introduction: Simple limitations of stochastic processes, stochastic phenomena in nature, stochastic processes in physics, epistemological and ontological views regarding stochastic processes.

Probability theory and Lebesgue integrals: probability limitation, sample spaces, sigma algebra, sigma algebraic properties, event spaces, measured spaces, sizes, sized spaces, size properties, types of measures, probability measures, and Kolmogorov limitation for probability, probability spaces, mapping of measured variables, random variables, and its properties, distribution of random variables, simple functions, simple function sequence construction for measurable functions, Lebesgue integrals for simple functions, Lebesgue integrals for any measurable function, Lebesgue integrals and their mean, variance, covariance, properties of Lebesgue integrals.

Stochastic Processes: technical mathematical limitations of stochastic processes, filter concept, filters built by stochastic processes, distribution of stochastic processes, Brownian motion, martingale and semimartingale, Ito and Stratonovich integrals, stochastic differential equations, Fokker-Planck equations.

Applied in physics: stochastic mechanics, stochastic quantum mechanics, econophysics.

REFERENCES

1. Erhan Cinlar, 2011, Probability and Stochastics, Graduate Text in Mathematics 261, Springer Verlag, Berlin.
2. Bernt Øksendal, 2000, Stochastic Differential Equation; An Introduction with Application, Springer-Verlag.

MFF 5005 GROUP THEORY FOR PHYSICIST
MFF 5005 *Group Theory for Physicist*
(2 Credits Elective Course Odd
Semester)

PREREQUISITE
None

LEARNING OBJECTIVES
After taking this course, students are able to:

CO 1. Understand and master the basic concepts of group theory and important examples in physics.
CO 2. Understand and master the concepts of homomorphism and group isomorphism.
CO 3. Understand and master the concept of group action and its types and group representation theory.
CO 4. Understand and master the concept of group and matrix Lie algebra along with their properties as well as important examples that are well-known in their application in physics.
CO 5. Understand the application of group theory in modeling, explaining, and solving problems in physics.

SYLLABUS

1. Semigroups and groups: Binary operations, binary operation associations, semigroups, identity elements, inverse elements, group boundaries, examples of important groups in physics, subgroups, characterization of subgroups, normal subgroups, conjugations, and conjugate classes, costs, factor groups, direct product, semi-direct product.
2. Homomorphism: Limitation of homomorphism, isomorphism, homomorphism properties, homomorphism kernel, homomorphism shadow, factor group of homomorphism, representation (representative).
3. Action Group: action limitation, action kernel, stabilizer, rigid point, action orbit, free action, effective action, transitive action, action effect bijection.
4. Matrix Lie Groups: matrix sequence convergence, Matrix Lie group boundary, examples, exponential matrix, matrix exponential properties, how to calculate exponential matrix, single parameter subgroups, single parameter subgroup generator, Lie Matrix Algebra, and its properties.
5. Representation theory: group representation, representative space, dimensional representation, representative reduction, Schur's lemma, matrix representation, unitary representation, regular representation.
6. Applied in physics: applied in quantum mechanics, applied in crystals, applied in particle physics, applied in geometric mechanics.

REFERENCES

1. Brian C. Hall, 2015, Lie groups, Lie algebras, and representations: an elementary introduction, Graduate Text in Mathematics 222, Springer Verlag, Berlin.
2. J. F. Cornwell, 1999, Group Theory in Physics, Academic Press, New York.

MFF 5007 TOPOLOGY AND GEOMETRY FOR PHYSICIST

MFF 5007 *Topology and Geometry for Physicist*

(2 Credits of Elective Course Odd Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this course, students are able to:

CO 1. Understand and master the basic concepts and main theorems of topology.

CO 2. Understand and master the concept of continuous mapping between topological spaces, homeomorphisms, and their properties.

CO 3. Understand and master the concepts of coordinate systems, atlases, differential structures, and differential manifolds.

CO 4. Understand and master the concept of differentiability mapping between differentiable manifolds.

CO 5. Understand and master the concepts of curves, functions (scalar fields), tangent vectors, covectors, tangent bundles and companion tangents, vector fields and covector fields.

CO 6. Understand and master the concept of tensors, tensor strands on a manifold, and tensor fields.

CO 7. Understand and master semi-Riemannan geometry and symplectic geometry.

CO 8. Understand and master the role and application of geometry in physical studies: general relativity and geometric mechanics.

SYLLABUS

Topology: Limitations of topology and topological space, open and closed set, examples of topological space, inheritance topology, product topology, closed set properties, mapping between topological spaces, homeomorphism, topological invariance, connectivity, compactness. Differentiable assortment: map or local coordinate system with n dimensions in topological space, differentiable assortment: map or local coordinate system with dimensions in topological space, compatibility of two local coordinate systems, atlas in topological space, the equivalence of two atlases, differential structure and differential diversity concept, differential mapping, differentiated functions, differential curves, local representation or coordinate representation of differential mapping, Lie group limitation.

Vector fields and covector fields: tangent vectors, tangent spaces, companion tangent spaces, covectors, local representatives of tangent vectors and covectors, tangent strands and covectors, vector fields and covector fields, integral curves, single parameter local groups, systems of differential equations, distributions, manifold integral distribution.

Tensor fields: tensors, covariance and contravariant tensors, tensor algebra, tensor space, tensor strands, tensor fields. Pseudo-Riemann geometry: tensor metric fields, pseudo-Riemann metrics and their properties, curve lengths, energy functions, geodesics, Christoffel symbols, metric connections and covariance derivatives, Riemann curvature tensor fields, Ricci tensors, Ricci scalars.

Connections and curvature: general connections on tangent strands, general covariance derivatives, curvature and Riemann curvature tensor, torsion and torsion tensor fields, Ricci tensor fields and Ricci scalars, Bianchi identity.

Applied Physics: space-time theory and geometric mechanics.

REFERENCE

Jeffrey M. Lee, 2009, Manifolds and Geometry Differential, Graduate Studies in Mathematics 104, American Mathematical Society, New York

MFF 5027 COMPUTATIONAL PHYSICS

MFF 5027 *Computational Physics*
(3 Credits of Compulsory Course
Odd Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this course, students are able to:

CO 1. Formulate and provide (to describe) the physical phenomena that are being studied and reveal important information contained in the physics problem through various tricks or certain mathematical procedures and utilize various approaches (approximations).

CO 2. Solve a problem with structured solutions (well-defined solutions), formulate a problem carefully and try other approaches (approaches) in an effort to improve the solution of a challenging problem.

CO 3. Conduct a search for physics problems from various sources and references to get an understanding of important information.

CO 4. Apply various forms of visualization, graphics or simulations through computer assistance and the use of appropriate software, programming languages and packages or numerical tools.

SYLLABUS

Summary of numerical methods: Computational error analysis, numerical interpolation and integration methods, iteration methods to find the zero point (root), numerical derivation and integration, a system of linear equations, function approximation, matrix inversion, and eigenvalue problems. Numerical methods for solving differential and integral equations. Fast Fourier Transform.

Basic understanding of Computational Physics: Finite difference presentation of differential and integral operators, solving nonlinear equations, initial condition problems, boundary condition problems, numerical solutions for n-dimensional systems, application of various methods to various physics cases.

REFERENCES

1. Conte S.D. dan de Boor, C., 1980, Elementary Numerical Analysis, An Algorithm Approach, 3rd ed., McGraw-Hill Press.
2. W.H. et al, 1987, NUMERICAL RECIPES, The Art of Scientific Computing, dan Vetterling.

3. W.T. et al, Numerical Recipes Examples Book (FORTRAN), Cambridge University Press.
4. Veseley, F.J., 1994, Computational Physics, Plenum Press.
5. Koonin, S.E., 1986, Computational Physics, Addison-Wesley Co.

MFF 5032 COMPUTATION OF CELESTIAL BODY MECHANICS

MFF 5032 *Computation of Celestial Body Mechanics*

(2 Credits of Elective Course Even Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this course, students are able to:

CO 1. Understand Julian Time and Day, Gregorian Calendar and Hijri Calendar, Earth and Spherical Triangle.

CO 2. Understand Spherical Coordinate System, Coordinate System Transformation, Low Accuracy Algorithm of Sun Position.

CO 3. Understand the Sun Position with Jean Meeus Algorithm, Moon Position with Browne Algorithm, and Moon Position with Jean Meeus Algorithm.

CO 4. Understand the Moon Phases with Jean Meeus Algorithm, Moon Phase with Moon-Sun Position Algorithm, Calendar, and Moon Phases.

CO 5. Understand Lunar Eclipses and Solar Eclipses.

SYLLABUS

Time and calendar. Earth and spherical coordinates, ecliptic coordinates, equator, and horizon. Sun position algorithm: low accuracy, Meeus and VSOP, application on prayer times and day duration. Moon position algorithm: Brown, Meeus, and ELP. Meeus algorithm for moon phases. Algorithm of lunar and solar eclipses: Meeus and VSOP.

REFERENCES

1. Meeus, J., 1998, Astronomical Algorithm, edisi kedua, Willmann-Bell, USA.
2. Anugraha R., 2012, Mekanika Benda Langit, Jurusan Fisika UGM.

MFF 5039 SPECIAL TOPICS IN COMPUTATIONAL PHYSICS

MFF 5039 *Special Topics in Computational Physics*

(3 Credits of Compulsory Course Odd Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this course, students are able to:

CO 1. Develop algorithms to translate physical problems into computer language and understand the concept of discretization.

CO 2. Understand finite difference computing methods.

CO 3. Understand different element computation methods.

CO 4. Apply presented computational methods to solve complex physical problems numerically.

SYLLABUS

The material includes the Finite difference method, Finite Element method, High-order partial differential equation solution method (Elliptic, parabolic and hyperbolic equations), and Monte Carlo method.

REFERENCES

1. Numerical Methods, 3rd eds, 2002, Doug Faires and Dick Burden.
2. Numerical Methods for Engineers 6 Ed. Chapra SC and Canale S.
3. Pang, T, 2006, An introduction to computational physics, Cambridge University Press.
4. J.M., Thijssen, 1999, Computational Physics, Cambridge University Press.

MFF 5034 MEKANIKA KUANTUM LANJUT

MFF 5034 *Advanced Quantum Mechanics*

(3 Credits of Elective Course Even Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this course, students are able to:

CO 1. Understand symmetry, sustainability, and degeneration; parity symmetry, time reversal, and lattice translation; theory of time-independent disorder decreased and increased cases.

CO 2. Understand application to the atomic hydrogen bath; variation method and WKB method; the theory of time-independent disorder.

CO 3. Understand to the application of perturbation theory to interactions with classical radiation fields; identical particles, permutation symmetry, and Young's table; scattering theory: Lippmann-Schwinger equation, Born approach.

CO 4. Understand Optical Theorems and Econal approximations; Partial wave method; Resonant scattering.

CO 5. Understand time-dependent scattering formulation; electron-atom scattering and Coulomb scattering.

SYLLABUS

Understanding the experimental aspects and mathematical structures of quantum mechanics and their application to various atomic/nuclear phenomena include the principles and various formulations of quantum mechanics, operators, implementations and properties, symmetrical one-dimensional and three-dimensional spherical potentials, and rotational angles of momentum. Identical particle systems and the Pauli principle, scattering, perturbation theory, and their implementation.

REFERENCES

1. Sakurai, J.J., 1985, Modern Quantum Mechanics, Benjamin Cummings.
2. Tannoudji, C.H., et al, 1977, Quantum Mechanics Vol.I & II., John Willey.

MFF 5056 FRACTAL AND CHAOS IN PHYSICS

MFF 5056 *Fractal and Chaos in Physics*
(2 Credits of Elective Course Even
Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this course, students are able to:

CO 1. Knowing several types of nonlinear phenomena generating systems, both physical systems and mathematical models.

CO 2. Obtain and visualize non-linear data series.

CO 3. Perform qualitative and quantitative analysis of nonlinear data using computer programs.

CO 4. Solve nonlinear differential equation models and apply quantitative analysis to the results obtained.

SYLLABUS

1. The concepts of turbulence, fractals, chaos, spatiotemporal chaos and phenomena in their physical systems (Brown motion, fluid systems, and liquid crystals).
2. Non-linear data analysis: spatiotemporal plot, phase space-based analysis, spectral analysis, autocorrelation, and Lyapunov exponential analysis.
3. Introduction to models and computation of nonequilibrium/non-linear (differential) equations: Langevin, Logistic Map, Korteweg-de Vries.
4. Amplitude Equations: Ginzburg-Landau, Swift-Hohenberg, Newell-Whitehead, Nikolaevsky.

REFERENCES

1. *Deterministic Chaos. An Introduction. Fourth, Revised and Enlarged Edition.* Heinz Georg Schuster, Wolfram Just, 2005 WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim.
2. Nonequilibrium Statistical Mechanics, Robert Zwanzig, Oxford Univ Press.
3. Addison, P., 1997, Fractals and Chaos, Philadelphia, IOP Pub.
4. Thomsou, J.M.T. dan Stewart, H.B., 1986, Nonlinear dynamics and chaos: geometrical methods for engineers and scientists, John-Wiley & Sons.

MFF 5114 PARTICLE PHYSICS

MFF 5114 *Particle Physics*

(3 Credits of Elective Course Even Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this course, students are able to:

CO 1. Understand abelian symmetries and Feynman diagram rules for quantum electrodynamics, and calculate cross-section and decay rate using simple Feynman diagrams for quantum electrodynamic interactions.

CO 2. Understand non-Abelian tera symmetry, electroweak interactions, quantum chromodynamics, and calculate cross-section and decay rate using simple Feynman diagrams for electroweak interactions and quantum chromodynamics.

CO 3. Understand the standard model, symmetry breaking, Higgs mechanism, and be able to calculate the approximation mass of the weak interaction tera field.

CO 4. Understand the hadron structure and calculate simple equations related to the hadron structure.

SYLLABUS

The background and the latest conditions for the development of particle physics. Quantum electrodynamics of spinless particles, Klein Gordon equations, Quantum electrodynamics of spin particles 1/2, Dirac's equations. Abelian Symmetry, Quantum Electrodynamics interactions, Feynman diagram rules for Quantum Electrodynamics. The symmetry of Non-Abelaneous Tera, Electroweak Interactions, Quantum Chromodynamics, Standard Models, Symmetry Destruction and the Higgs Mechanism, Hadron Structure. Standard Model Extension.

REFERENCES

1. Halzen, F dan Martin, A.D., 1984, Quarks and Leptons, An Introductory Course in Modern Particle Physics, John-Wiley, New York.
2. Mandl, F., 1966, Introduction to Quantum Field Theory, Wiley Interscience, New York.
3. Perkins, D. H., 1982, Introduction to High Energy Physics, Addison-Wesley.

MFF 5115 QUANTUM FIELD THEORY

MFF 5115 Quantum Field Theory

(3 Credits of Compulsory

Course Odd Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this course, students are able to:

CO 1. Explain the cohesive relationship between particular relativity theory and quantum mechanics in quantum field theory.

CO 2. Describe the non-interaction field solution for the Klein-Gordon equation and the Dirac equation.

CO 3. Explain the various discrete and continuous symmetries in Lagrangian field theory, particularly Klein Gordon's Lagrangian and Dirac's Lagrangian.

CO 4. Calculate scattering cross-section and decay rate using a simple lowest-order Feynman diagram.

CO 5. Analyze some simple problems in particle physics phenomena using quantum field theory.

SYLLABUS

Classical field theory, Noether theorem, Klein Gordon field, Klein Gordon field quantization, Dirac field, Dirac field quantization, Discrete Symmetry charge conjugation, parity and time reversal (CPT), Perturbation theory, Wick theorem, Feynman diagrams, Latitudes and matrix-S, Feynman's rules for quantum electrodynamics, Basic processes in quantum electrodynamics: Electron-muon scattering, muon production, Compton scattering, Annihilation of electron pairs into photons.

REFERENCE

M.E. Peskin dan D.V. Schroeder, 1995, An Introduction to Quantum Field Theory, Perseus Book, Massachusetts.

MFF 5211 NUCLEAR PHYSICS

MFF 5211 *Nuclear Physics*

(3 Credits of Compulsory Course Odd Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this course, students are able to:

CO 1. Explain the structure of the nucleus which includes nuclear binding energy and nuclear energy levels. Analyze the stability of a core.

CO 2. State the types of nuclear reactions and their classification. Calculate the reaction energy, the kinetic energy of the nuclei involved in the reaction and the detection method.

CO 3. Students are able to state the types of nuclear reactions (fission and fusion) and their classification.

CO 4. Explain the scattering and reactions of neutrons and their applications.

SYLLABUS

1. Core Structure: Petals Model, Nuclear binding energy, and nuclear stability.
2. Decay: Alpha, gamma, beta decay terms, gamma decay classification, beta.
3. Nuclear reaction model: nuclear reaction type, Nuclear reaction energy, partial wave method, reaction cross section, Coulomb and Nuclear scattering, compound reaction, direct reaction, resonant reaction, heavy nuclear reaction.
4. Fission Reaction: fission reaction process, fission reaction characteristics, fission reaction energy, reactions in fission reactors.
5. Neutron reactions: neutron sources, neutron detection, neutron reaction cross-sections, neutron capture, neutron diffraction.
6. Fusion reaction: the process of fusion reactions, characteristics of fusion reactions, fusion reactions in stars.
7. Nuclear reaction applications: Neutron scattering applications, BNCT, combustion in Stars.

REFERENCES

1. K. Krane, 1988, Introductory Nuclear Physics, John Wiley & Sons.
2. J. L. Basdevant.,J. Rich., dan J. Spiro.,2005, Fundamental In Nuclear Physics, Springer, New York.

MFF 5022 FUNCTIONAL ANALYSIS FOR PHYSICIST

MFF 5022 *Functional Analysis for Physicist*
(2 Credits of Elective Course Even
Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this course, students are able to:

CO 1. Understand and master the basic concepts of functional analysis.
CO 2. Understand and master the main theorems of functional analysis.
CO 3. Understand some examples of the application of functional analysis in Physics.
CO 4. Apply functional analysis in physics problems.

SYLLABUS

Hilbert space, Geometry of Hilbert space, orthonormal basis, operator theory in Hilbert space, types of operators in Hilbert space, Bancah space, operator theory in Bancah space, Hahn-Banach theorem, spectral theorem, its application in physics.

REFERENCES

1. *Linear Operators in Hilbert Space*, Joachim Weidmann, Springer-Verlag, Berlin, 1980.
2. *Elementary Functional Analysis*, Barbara D. MacCluer, Springer-Verlag, Berlin, 2009.

MFF 5982 COSMOLOGY

MFF 5982 *Cosmology*
(3 Credits of Elective Course Even Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this course, students are able to:

CO 1. Understand the definition of introduction, fundamental observations of cosmology; General relativity as the basis of cosmology (TRU mathematical tools: Covariance Principle, tensor, metric, covariance derivative, Einstein tensor, momentum-energy tensor, geodesic equations, Einstein equations, some examples of solving Einstein equations); Cosmic dynamics (cosmological principles, Robertson Walker metrics, proper distance, Friedmann equations, fluid and acceleration equations, equations of state, cosmological constants).

CO 2. Understand the single component universe (Evolution of energy density, universe only with curvature component, spatially flat universe, universe with material component, universe with radiation component, universe with lambda component); Multiple-component universe (curvature-matter, lambda-matter, lambda-curvature-matter, matter-radiation, benchmark model); Measuring cosmological parameters (two numbers, luminosity distance, angular-diameter distance, standard candle-Hubble parameter-acceleration).

CO 3. Understand the Dark matter (visible matter, dark matter in galaxies and galaxy clusters, candidate of dark matter); Dark Energy (dark energy indirect detection, dark energy alternative); Cosmic microwave Background radiation (CMB observations, recombination, and decoupling, recombination physics, temperature fluctuations).

CO 4. Understand the Early universe (thermodynamic equilibrium, entropy, Boltzmann equation, Saha equation); Early Universe (out-off equilibrium, thermal history of the universe)); Big Bang Nucleosynthesis (Nuclear Statistical equilibrium, initial conditions, light element production, primordial abundance: prediction and observation).

CO 5. Understand the Inflation (flatness problem, horizon problem, inflation solution, inflation as a scalar field, density perturbations and relic gravity, specific models); Structural formation (evolution of density inhomogeneity, the spectrum of density perturbations, two stories: hot and cold dark matter, probing the primeval spectrum, the omega problem).

SYLLABUS

1. Introduction, Observation of cosmological fundamentals, General relativity as fundamentals of cosmology.
2. TRU mathematical devices: Covariance principle, tensor, metric, covariant derivative, Einstein tensor, energy-momentum tensor, geodesic equation, Einstein equation, some examples of Einstein equation solutions.
3. Cosmic dynamics: cosmological principles, Robertson Walker's metric, proper distance, Friedmann's equations, fluids and acceleration equations, state equations, cosmological constants.
4. Single component universe: Universe only with curvature component, the spatially flat universe, the universe with a material component, the universe with radiation component, the universe with a lambda component.
5. Multiple-component universe: matter-curvature, matter-lambda, matter-curvature-lambda, radiation-matter, benchmark model.
6. Cosmological parameters: two numbers, luminosity distance, angular-diameter distance, standard candle-Hubble parameter-acceleration.
7. Dark matter: visible matter, dark matter in galaxies and galaxy clusters, candidate of dark matter.
8. Dark Energy: indirect detection of dark energy, an alternative to dark energy.
9. Cosmic microwave Background radiation: CMB observation, recombination, and

decoupling, recombination physics, temperature fluctuations.

10. Early universe: thermodynamic equilibrium, entropy, Boltzmann equation, Saha equation, out-off equilibrium, thermal history of the universe.
11. Big Bang Nucleosynthesis: Nuclear Statistical equilibrium, initial conditions, light element production, primordial abundance: predictions and observations.
12. Inflation: flatness problem, the horizon problem, inflation solution, inflation as a scalar field, density perturbations and relic gravitation, specific models.
13. Structure Formation: evolution of density inhomogeneity, spectrum of density perturbations, two stories: hot and cold dark matter, probing the primeval spectrum, the omega problem.

REFERENCES

1. Kolb, E.W & Turner, M.S., The Early universe, 1989, Addison-Wesley Publishing Company.
2. Ryden, B. Introduction of Cosmology, 2016, Department of Astronomy, The Ohio State University.
3. Raine, D.J & Thomas, E.G, An Introduction To The Science Of Cosmology, 2001, IOP Publishing.
4. Scott Dodelson, Modern Cosmology, 2003, Academic Press.
5. Cheng T., 2005, Relativity, Gravitation, and Cosmology. A basic introduction, Oxford University Press, Oxford.

MFF 5514 CONDENSED MATTER ELECTRONICS STRUCTURE COMPUTATION

MFF 5514 *Condensed Matter Electronics Structure Computation*

(2 Credits of Elective Course Even Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this course, students are able to:

- CO 1. Describe and evaluate the use of computational methods in solving the problem of the electronic structure of condensed matter.
- CO 2. Describe and discuss the completion of eigenvalues by the Numerov method, factorization, diagonalization, self-consistent field, and Hartree-Fock.
- CO 3. Describe and discuss the Tight-Binding method in solving the problem of the electronic structure of condensed matter.
- CO 4. Describe and discuss the first principle-density functional theory (DFT) method in solving the problem of the electronic structure of condensed matter.
- CO 5. Interpret and correlate between experimental data (optical spectroscopy and electron spectroscopy) and computational calculations for many-particle systems (example: for 2D materials).

SYLLABUS

Theory of electronic and atomic structures, molecules and solids, factorization and iteration methods for eigenvalues problems, pseudo-potential models of field waves, integration of Brillouin zones, Self-Consistent Field, Hartree-Fock Method, Tight Binding Method, Density Functional Theory (DFT) Method, Classical molecular dynamics model, and Car-Parrinello Lagrangian.

REFERENCES

1. Richard Martins, 2004, Electronic Structure, Cambridge University Press.
2. J.M., Thijssen, 1999, Computational Physics, Cambridge University Press.
3. Haile, J.M., 1992, Molecular Dynamics Simulation, John-Wiley & Sons, Inc.

MFF 5010 LOGIKA DAN KOMPUTASI SIMBOLIK DALAM FISIKA

MFF 5010 *Logic and Symbolic Computation in Physics*

(2 Credits of Elective Course Even Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this course, students are able to:

- CO 1. Understand the notion of numerical computing, truncation errors, and rounding off.
- CO 2. Understand the notion of symbolic computing in general, syllogisms, and their application in physics.
- CO 3. Understand the computation of diagrams and integers in syllogism solutions, the notion of symbolic computing in particular (processing of mathematical expressions).

CO 4. Understand the notion of symbolic computing (processing of mathematical expressions), symbolic programming languages, and examples of their use.

CO 5. Understand the merging of symbolic and numeric computing.

SYLLABUS

1. Numerical computing definition: truncation and rounding error. The notion of symbolic computing in general. The syllogism and its applications in physics. Computation of diagrams and integers in Syllogism solutions.
2. The notion of symbolic computing specifically: processing of mathematical expressions. Symbolic programming languages and examples of their use. Merging symbolic and numerical computations.

REFERENCES

1. A G Grozin, 1997, Using REDUCE in High Energy Physics, Cambridge Univ Press.
2. Hermanto, 2015, Bahan ajar Logika dan Komputasi Simbolik, FMIPA-UGM.

MFF 5041 TEORI RELATIVITAS UMUM

MFF 5041 *General Theory of Relativity*
(3 Credits of Compulsory Course Odd Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this course, students are able to:

CO 1. Understand the theory of special relativity: Einstein's postulates for special relativity, Lorentz transformations, Minkowski space, cones of space-time and causality, world lines, self-time, observers, Equivalence and covariance principles, weak equivalence principle, equivalence principle, Einstein equivalence principle, covariance principle, the effect of the principle of equality.

CO 2. Understand Diversity Theory, maps and atlases, maximum atlases, differential structures, smooth variance, curves and functions, tangent vectors and companion tangent vectors, tangent spaces and companion tangent spaces, vector fields and companion vector fields, Lie derivative curves and Lie brackets, algebraic fundamentals basis for tensor, tensor field, tensor interpretation, local base, tensor component.

CO 3. Understand the transfer of tensor varieties, tensor products, contractions, Lie derivatives, tensor derivatives, differential forms, and symmetrical bilinear forms. Semi-Riemannian diversity: metric tensors, isometry, metric index, Levi-Civita connections, parallel shifts, covariance derivatives, geodesic and geodesic equations, exponential mapping, Riemann curvature, frame fields, Ricci curvature, and Ricci scalars.

CO 4. Understand energy, matter, gravity, and geometry: energy and momentum tensor, momentum energy tensor for some cases: dust, perfect flow of matter, classical field equations, the relationship between space-time geometry with energy and matter, the relationship between space-time curvature and matter dynamics.

CO 5. Understand Einstein's field equations, Einstein's field equations formulation, properties of Einstein's field equations, Schwarzschild's Answer.

SYLLABUS

1. Special relativity theory: Einstein's postulates for special relativity, Lorentz transformation, Minkowski space, cone of space-time and causality, worldline, self-time, observers.
2. Principle of equivalence and covariance: weak equivalence principle, equivalence principle, Einstein equivalence principle, covariance principle, the effect of the equivalence principle.
3. Diversity Theory: maps and atlases, maximum atlases, differential structures, smooth variances, curves and functions, tangent vectors and companion tangent vectors, tangent spaces and companion tangent spaces, vector fields and companion vector fields, Lie derivative curves and Lie brackets, algebraic fundamentals base for tensor, tensor fields, tensor interpretation, local bases, tensor component, tensor variety transfer, tensor products, contraction, Lie derivative, tensor derivative, differential form, symmetric bilinear form.
4. Semi-Riemannian diversity: metric tensor, isometry, metric index, Levi-Civita connection, parallel shift, covariance derivative, geodesic and geodesic equations, exponential mapping, Riemann curvature, frame plane, Ricci curvature, and Ricci scalars.
5. Energy, matter, gravity, and geometry: energy and momentum tensor, momentum energy tensor for some cases: dust, perfect flow of matter, classical field equations, the relationship between space-time geometry with energy and matter, the relationship between space-time curvature and matter dynamics.

REFERENCES

Carroll S., 2004, Spacetime and Geometry. An Introduction to General Relativity, Addison- Wesley, New York.

MFF 5951 ASTROPHYSICS

MFF 5951 *Astrophysics*

(3 Credits of Compulsory Course Odd Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this course, students are able to:

CO 1. Understand the structure, properties of stars, and their radiation spectrum (luminosity, H.R. diagram), star population (mass and age), distance and magnitude, impermeability and radiative forcing, mechanical equilibrium in stars (equations of momentum and continuity, potential energy, virial theorem for stars).

CO 2. Understand the mechanical equilibrium in a rotating star (equilibrium configuration, stellar structural equations for skin rotation), energy balance in stars (radiation transfer, energy balance), the rate of energy generation from gravitational collapse, and temperature and density changes for adiabatic contraction.

CO 3. Understand the secular stability of nuclear combustion, the role of radiation pressure in stars, Energy conservation and radiative equilibrium for a rotating star, the radiative equilibrium for a rotating star, radiation transfer for a rotating star, interactions between rotation and radiation effects, and threshold rotational velocity.

CO 4. Understand Convection in stars, gravitational waves in stars, Mixing-Length theory for convective flow, convection in the interior of stars, Non-adiabatic convection, convection in the brightest stars, Galaxy classification of galaxies, elliptical galaxies, disk galaxies, spiral galaxies, Milky Way, galaxies dwarfs, active galactic nuclei, galaxy population statistical properties.

CO 5. Understand the structure of the Galaxy, distribution of stars, chemical composition and age, gas and dust in the galaxy, cosmic rays, distance to the center of the galaxy, the location of the center of the galaxy, central star clusters, Galactic Kinematics, determination of star velocity, rotation curve of a galaxy.

SYLLABUS

1. Structure, properties of stars, and their radiation spectrum (luminosity, H.R. diagram), star population (mass and age), distance and magnitude, impermeability, and radiative forcing. Mechanical equilibrium in stars: equations of momentum and continuity, potential energy, virial theorem for stars.
2. Mechanical equilibrium in a rotating star: equilibrium configuration, stellar structural equations for shell rotation.
3. Energy balance in stars: radiation transfer, energy balance, the rate of energy generation from gravitational collapse, temperature and density changes for adiabatic contraction, secular stability of nuclear combustion, and the role of radiation pressure in stars.
4. Energy conservation and radiative equilibrium in a rotating star: radiative equilibrium in a rotating star, radiation transfer for a rotating star, interactions between rotation and radiation effects, threshold rotational velocity.
5. Convection in stars, gravitational waves in stars, Mixing-Length theory for convective flow, convection in the interior of stars, Non-adiabatic convection, and convection in the brightest stars.
6. Galaxy: classification of galaxies, elliptical galaxies, disk galaxies, spiral galaxies, Milky Way, galaxies dwarfs, active galactic nuclei, galaxy population statistical properties.
7. Galaxy Structure: distribution of stars, chemical composition and age, gas and dust in the galaxy, cosmic rays, distance to the center of the galaxy, the location of the center of the galaxy, central star clusters.
8. Galactic Kinematics: determination of star velocity, rotation curve of a galaxy.

REFERENCES

1. Maeder A., 2009, Physics, Formation and Evolution of Rotating Stars, Springer-Verlag, Berlin.
2. Bradt H., 2008, Astrophysics Processes, Cambridge University Press, Cambridge.
3. Prialnik D., 2000, Introduction to the theory of Stellar Structure and Evolution, Cambridge University Press, Cambridge.
4. Schneider P., 2006, Extragalactic Astronomy and Cosmology. An Introduction, Springer Verlag, Berlin.

5. Sparke L.S., dan Gallagher III J.S., 2007, Galaxies in the Universe: An Introduction, 2nd Ed, Cambridge University Press.
6. Pradhan A.K. dan Nahar S.N., 2011, Atomic Astrophysics and Spectroscopy, Cambridge University Press, Cambridge.

MFF 5404 FLUID MECHANICS

MFF 5404 *Fluid Mechanics*
(3 Credits of Elective Course
Even Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this course, students are able to:

CO 1. Understand the introduction of flowing substances, physical properties of flowing substances, flow mechanics and their role in physics, basic concepts of continuous medium mechanics, ideal flowing substances, Lagrange's descriptions, and Euler's descriptions.

CO 2. Understand the concept of kinematics, mass conservation equation, momentum conservation equation, energy conservation equation, momentum flux, energy flux, potential flow, and sound wave propagation.

CO 3. Understand the instability of flowing substances, viscous liquids, equations for viscous fluids, energy dissipation, some examples, viscosity due to suspension, and correct answers to equations of motion of viscous liquids.

CO 4. Understand multiple applications: the equation of flowing substance in various coordinate systems, stars as fluid systems, accretion disks in astrophysics, etc.

CO 5. Understand the substance of relativistic flow and turbulence.

SYLLABUS

1. Introduction: flowing substances, physical properties of flowing substances, flow mechanics and their role in physics, basic concepts of continuous medium mechanics.
2. Ideal flowing substances: Lagrange's descriptions and Euler's descriptions, the concept of kinematics, mass conservation equation, momentum conservation equation, energy conservation equation, momentum flux, energy flux, potential flow, sound wave propagation, and the instability of flowing substances.
3. Viscous liquids: equations for viscous fluids, energy dissipation, some examples, viscosity due to suspension, correct answers to equations of motion of viscous liquids.
4. Multiple applications: the equation of flowing substance in various coordinate systems, stars as fluid systems, accretion disks in astrophysics, etc.
5. Optional: relativistic flow substance, turbulence.

REFERENCES

1. Clarke C.J. dan Carswell R.F., 2007, Principles of Astrophysical Fluid Dynamics, Cambridge University Press, Cambridge.
2. Batchelor G.K., 2000, An Introduction to Fluid Dynamics, Cambridge University Press, Cambridge.

3. Landau L.D. dan Lifshitz E.M., 1987, Fluid Mechanics, edisi kedua, Pergamon Press, New York.

ELECTIVE COURSES
KBK APPLIED PHYSICS

MFF 5061 METHODS OF EXPERIMENTAL PHYSICS

MFF 5061 *Methods of Experimental Physics*

(3 Credits of Compulsory Course Odd Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this course, students are able to:

CO 1. Handle errors in measurement.
CO 2. Use basic statistics to analyze experimental data.
CO 3. Design experiments to solve problems in measuring physical quantities and develop measurement methods

SYLLABUS

Experimental Strategy, Multiple Experimental Design Applications, Simple Comparison Experiments, Experiments with Single Factors, Development of experimental theories and methods, instrumentation, and data analysis in various fields of Classical and Modern Physics, with an emphasis on fostering and developing research skills and students' skills of critical attitude towards experimentation physics methodology; Postgraduate research design.

REFERENCES

1. Douglas C. Montgomery, 2001, Design and Analysis of Experiment, JohnWiley and Son.
2. Frederick James, 2006, Statistical Methods in Experimental Physics, World Scientific.
3. Hugh D. Young, 2009, Statistical Treatment of Experimental Data, McGraw Hill Book Company Inc.

MFF 5281 RADIATION PHYSICS

MFF 5281 *Radiation Physics*

(3 Credits of Compulsory
Course Odd Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this course, students are able to:

CO 1. Explain the characteristics of the nucleus, nuclear models, and nuclear force systems.

CO 2. Explain the theory of gamma decay, alpha decay theory, beta decay theory, and nuclear reactions.
CO 3. Explain the angular correlation in decay and nuclear reactions, artificial radiation sources (x-ray generators and accelerators) and natural (isotopes), open and closed radiation sources.
CO 4. Explain the interaction of radiation with materials, radiation detectors, radiation activity.
CO 5. Explain the amount and unit of radiation, radiation protection system.

SYLLABUS

Nuclear characteristics, nuclear models, and nuclear force systems. The theory of alpha, gamma, beta decay, nuclear reactions, angle correlations in decay, and nuclear reactions. Artificial sources of radiation (x-ray generators and accelerators) and natural sources of radiation (isotopes). Open and closed radiation sources. Interaction of radiation with materials. Radiation detector, radiation activity, radiation quantity, and unit. Radiation protection system.

REFERENCES

1. Kiefer, H. and Maushart, R., 1972, Radiation Protection and Measurement. Pergamon Press.
2. Knoll, G.F., 1979, Radiation Detection and Measurements, Pergamon Press.
3. Krane, K.S., 1988, Introductory Nuclear Physics, John Wiley and Sons.

MFF 5321 ATOMIC AND MOLECULAR SPECTROSCOPY

MFF 5321 *Atomic and Molecular Spectroscopy*

(3 Credits of Compulsory Course Odd Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this course, students are able to:

CO 1. Explain concepts and solve cases related to Atomic and Molecular Structure.
CO 2. Explain concepts and solve cases related to Multiple Spectroscopic Methods.
CO 3. Work in groups to study the development of the Theory and Application of Atomic and Molecular Spectroscopy.

SYLLABUS

Summary of the quantum theory of atoms and molecules, the interaction between radiation and matter, and the selection rules. Atomic and molecular spectra, fine structure, hyperfine, outer field atomic interaction. Spectroscopic methods: inner electron spectroscopy, visible/optical spectroscopy, radio frequency spectroscopy, microwave, and infrared spectroscopy. Supporting equipment/components atomic and molecular spectroscopy.

REFERENCES

1. Svanberg, S., 1991, Atomic and Molecular Spectroscopy: Basic Concepts And Practical Applications, Springer-Verlag.

2. Sindu, P.S., 1985, Molecular Spectroscopy, Tata McGraw-Hill, India.
3. Demtroder, W., 1981, Laser Spectroscopy, Basic Concepts and Instrumentations, Springer-Verlag.
4. Graybeal, J. D., 1988, Molecular Spectroscopy, McGraw-Hill.

MFF 5423 LASER SPECSTROSCOPY

MFF 5423 *Laser Spectroscopy*

(2 Credits of Elective Course

Odd Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this course, students are able to:

CO 1. Menjelaskan konsep konsep Spektroskopi menggunakan Laser dan peralatan bantu (mekanik, optic maupun elektronik) sebagai landasan baku untuk menganalisis hasil (spectrum, numeric, pulsa) dari hasil interaksi cahaya laser dengan atom/molekul.

CO 2. Menjelaskan mekanisme interaksi antara cahaya laser dengan atom/molekul didasarkan pada kajian teoretiknya.

CO 3. Menjelaskan hasil yang diperoleh (numeric, spectrum) didasarkan atas kajian teoretiknya.

SYLLABUS

Introduction to spectroscopic, emission, and absorption methods. Limited Doppler spectroscopy methods: optogalvanic, optoacoustic, Opto-thermal, laser-induced fluorescence (LIF), resonance induced spectroscopy (RIS), resonance induced mass spectroscopy (RIMS), double resonant method, laser-induced breakdown spectroscopy (LIBS). Doppler-free spectroscopy methods, saturation, polarization methods (POLINEX), intermodulation (IMOGS), and level crossing spectroscopy. Reasoning/supporting components of laser spectroscopy with their applications and analysis.

REFERENCES

1. Svanberg S., 1991, Atomic and Molecular Spectroscopy: Basic concepts and practical applications, Springer-Verlag.
2. Demtroder, W., 1981, Laser Spectroscopy: Basic Concept and Instrumentation, Springer- Verlag.

MFF 5424 BIOMEDICAL OPTICS

MFF 5424 *Biomedical Optics*

(2 Credits of Elective Course Even Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this course, students are able to:

CO 1. Explain the concept and solve cases of photon propagation in biological tissues.

CO 2. Explain concepts and solve cases of imaging biological tissue objects subjected to photons.
CO 3. Work in groups to study the development of Photoacoustic Tomography Theory and Applications.

SYLLABUS
Introduction to Biomedical Optics; Single Scattering: Rayleigh Theory and Mie Theory; Monte Carlo Modeling of Photon Transport; Convolution for a wide beam of light; The radiative transfer equation and diffusion theory; Hybrid model of the Monte Carlo method and diffusion theory; Detection of optical properties and spectroscopy; Imaging and microscopy; Optical coherent tomography; Tomography.

REFERENCES

1. Wang L. V. and Hsin-i Wu, 2007, Biomedical Optics: Principles and Imaging, A John Wiley and Sons. Inc. Publication.
2. Wang L.V., 2009, Photoacoustic Imaging and Spectroscopy, Taylor &Francis Group, LLC CRC Press is an imprint of Taylor & Francis Group, an In forma business(e-Book).
3. Dinh T.V.,2003, Biomedical Photonic Handbook, CRC Press LLC.

MFF 5426 LASER PHYSICS
MFF 5426 *Laser Physics*
(2 Credits of Elective Course Even Semester)
PREREQUISITE
None

LEARNING OBJECTIVES
After taking this course, students are able to:
CO 1. Understand the mechanism of electron interaction in atoms so that students can use lasers, electronic auxiliary equipment and their use.
CO 2. Have an adequate understanding of the use of lasers for applications and analysis involving laser beam radiation.
CO 3. Increase cooperation in groups and the ability to convey ideas or thoughts, also improve the ability to think logically and creatively, which will indirectly foster leadership spirit through group work/discussion.
CO 4. Have skills in obtaining lecture materials from lectures provided by lecturers and other materials by searching through library books and the internet.

SYLLABUS
Introduction: Interaction of electromagnetic radiation with matter, quantization of electromagnetic fields. Laser principle: active laser material, pumping mechanism, optical resonator, optical radiation modulation, Q-switching, mode locking. Laser characterization: laser type, laser properties, laser classes, laser hazards, and how to deal with them. Laser Applications: in spectroscopy, agriculture, communication, medicine, industry, etc.

REFERENCES

1. Loudon, R.., 1985, Quantum Theory of Light, 2nd ed., Oxford UniversityPress.
2. Yariv, A., 1989, Quantum Electronics, 3rd ed., John Wiley & Sons.
3. Svelto, O., 1989, Principles of Laser, edisi 3 (terjemahan dalam Bahasa Inggris oleh D.C.Hanna), Plenum Press.
4. Miloni P.W. dan Eberly H., 1991, Lasers, John and Wiley.
5. Shimoda K., 1986, Introduction to Laser Physics, Springer Verlag.

MFF 5431 THEORITICAL ACOUSTICS

MFF 5431 *Theoretical Acoustics*

(2 Credits of Elective Course

Odd Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this course, students are able to:

CO 1. Analyze concepts and solve cases related to Acoustic Theory and Applications in the classical era.

CO 2. Analyze concepts and solve cases of Acoustic Theory and Applications in the modern era.

CO 3. Work in groups in reviewing the latest developments in Acoustic Theory and Applications.

SYLLABUS

Basic linear acoustics; Acoustic propagation in the atmosphere; Underwater acoustics; Physical acoustics; Photoacoustic; Thermo acoustic; Nonlinear acoustics in fluids; Acoustic signal processing; Acoustics and Structural Vibration; Medical acoustics; Photoacoustic tomography; Modulated ultrasound optical tomography.

REFERENCES

1. Rossing T.D., 2007, Handbook of Acoustics, Springer Science BusinessMedia, LLC New York.
2. Morse,P.M. and Ingard, K.U.,1968, Theoretical Acoustics, McGraw-HillBook Company, New York.

MFF 5434 PHOTOACOUSTIC AND PHOTOTHERMAL

MFF 5434 *Photoacoustics and Photothermal*

(2 Credits of Elective Course Even Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this course, students are able to:

CO 1. Understand the concepts and solve cases related to photoacoustic and photothermal phenomena.

CO 2. Understand the working principle of supporting equipment and design experimental set-ups for photoacoustic and photothermal systems.

CO 3. Understand the group's work in studying the development of photoacoustic and photothermal Theory and Applications.

SYLLABUS

Fourier transform photoacoustic spectroscopy of solids; Photoacoustic Detection of Light Shifts in Molecules; Step-and-Integration of Interferometry in Mid-Infrared with Photothermal Beam Deflection and Microphone Detection of Gas Samples; Photothermal Electrostatics of the Pd-PVDF Photoproelectric Hydrogen Gas Sensor; Photoacoustic Spectrum of Chlorinated Ethylene at CO2 Laser Frequency; Photothermal Deflection Technique (TDF): Fast Tracking Gas Detection in the Atmosphere; Measurement of Photoacoustic Gradient/Vertical Change of Ammonia in the Atmosphere; Photoacoustic and Photothermal Engineering Interfaces for Methodology and Instrumentation for Agricultural, Environmental and Medical Applications; In Situ Monitoring of Photoacoustic Gas Tracking in Rural Environments; Methane Photoacoustic Field Measurement; Liquid Nitrogen Cooling CO Laser in Photoacoustic Setting For Low Gas Concentration Monitoring; Photothermal Detection of Tracking Chemicals by Fiber Optic Interferometry Probe; Fiber Optic Laser Photoacoustic Spectroscopy for Detection of Organic Pollutants in Solution.

REFERENCES

1. Photoacoustic and Photothermal Phenomena, Proceedings of the 5th International Topical Meeting, Heidelberg, Fed. Rep. of Germany, July 27–30, 1987. Editors: Peter Hess and Josef Pelzl (Springer Series in Optical Sciences).
2. Photoacoustic and Photothermal Phenomena III, Proceedings of the 7thInternational Topical Meeting, Doorwerth, The Netherlands, August 26–30, 1991. Editors: Bicanic, Dane (Ed.) (Springer Series in Optical Sciences).

MFF 5841 MICROWAVE THEORY AND APPLICATIONS

MFF 5841 *Microwave Theory and Applications*

(2 Credits of Elective Course Odd Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this course, students are able to:

CO 1. Describe the development and advancement of microwave devices.

CO 2. Describe the reduction of TE and TM Variations in square wave monitors, cylinders, and able to convert microwave output power from mW to dBm or otherwise.

CO 3. Calculate the loss of microwave energy as it passes through the inhibiting component, the increase in microwave energy as it passes through the amplifying component, and the portion of the reflected microwave energy as it passes through the reflecting component.

CO 4. Explain the working principle of microwave signal control components.

CO 5. Describe the characteristics of microwave detectors and some microwave generators, such as semiconductors, klystrons, and Magnetrons.

CO 6. Explain the application of tomographic thermoacoustic systems.

SYLLABUS

Transmission Line Theory, Principles of microwave measurement, Microwave generating sources, Microwave signal analysis, Network analysis, Microwave application; ESC, modern communication, Radar system, and PAT.

REFERENCES

1. Stephen dan Packard, 2008, Microwave Theory and Applications.
2. Mitrayana.,2016, Teori dan Aplikasi Gelombang Mikro dan Aplikasinya,Gama PressUGM.
3. Allan W. Scott, 1993, Understanding Microwaves, John Wiley & Sons.

MFF 5878 IMAGE RECONSTRUCTION

MFF 5878 *Image Reconstruction*

(2 Credits of Elective Course Even Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this course, students are able to:

CO. 1 Explain tomography: transmission tomography, emission tomography, tomographic diffraction; magnetic resonance imaging, electron tomography, radar, vector tomography, and seismic tomography.

CO. 2 Explain the concepts of Stability: sampling and image resolution; Reconstruction algorithms: filtered back projection, Fourier reconstruction, iterative reconstruction; Linear tomography: pencil beam parallel, fan beam detector linear array, and curve array.

CO. 3 Explain focused fan beam, helical, 3D reconstruction; Special case tomography: loss of orientation, missing data, incomplete data; scanty tomography, discrete tomography, local tomography.

CO. 4 Explain Non-linear tomography: tomography with scattering; optical tomography, impedance tomography, ultrasound tomography.

SYLLABUS

Introductory mathematics: Fourier analysis, integral operators, general inverse, value decomposition, special functions, Fast Fourier Transforms, integral geometry, Radon transforms, vector fields. Tomography: transmission tomography, emission tomography, diffraction tomography, magnetic resonance imaging, electron tomography, radar, vector tomography, seismic tomography. Stability, sampling, and image resolution. Reconstruction algorithm: filtered back projection, Fourier reconstruction, iterative reconstruction. Linear tomography: pencil beam parallel, linear and curved array fan beam detector, focused fan beam, helical, 3D reconstruction. Special case tomography: loss of orientation, missing data, incomplete data, scanty data tomography, discrete tomography, local tomography. Non-linear tomography: tomography with scattering, optical tomography, impedance tomography, ultrasound tomography.

REFERENCES

1. Natterer, F. and Wubbeling F., 2001. Mathematical Methods in Image Reconstruction, SIAM, USA.
2. Kak, A.C. and Slaney M., 1988, Principles of Computed TomographyImaging, IEEE Press, Piscataway, NJ.
3. Suparta, G.B., 1999, “Focusing Computed Tomography Scanner”, Ph.D.
4. Thesis, Monash university, Merlbourne, Australia.

MFF 5876 METODE PENCITRAAN FISIKA

MFF 5876 *Imaging Methods in Physics*

(3 Credits of Elective Course Even Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this course, students are able to:

CO. 1 Explain Imaging Physics: medical applications, industrial applications, laboratory applications, research trends and applications of Image Physics. Fundamental Physics: The structure of matter, radioactive decay.

CO. 2 Explain the interaction of radiation with matter, the magnitude and measurement of radiation. Radiation sources: x-rays, gamma, Radiation sources: neutrons, positrons, beta.

CO. 3 Explain radiation sources: infrared, light, ultraviolet; Spectroscopy: photon detection, nuclear detection, particle detection, radiation power. ; Optical Imaging: microscope, photography, thermography.

CO. 4 Explain colonoscopy, videography, and time-lapse imaging. ; Radiography: system radiography, fluoroscopy, film radiography, computed tomography, direct radiography.

CO. 5 Explain Tomography: Principles of computer tomography, CT Scanner, PET, SPECT, Ultrasound CT Scan, Optical Tomography, 3D Tomography.

SYLLABUS

Imaging Physics: medical applications, industrial applications, laboratory applications, research trends, and Image Physics applications. Fundamental Physics: The structure of materials, radioactive decay, the interaction of radiation with materials, and the magnitude and measurement of radiation. Radiation sources: x-rays, gamma, neutrons, positrons, beta, infrared, light, ultraviolet. Spectroscopy: photon detection, detection detection, particle detection, radiation power. Optical Imaging: microscopy, photography, thermography, colonoscopy, videography, time-lapse imaging. Radiography: system radiography, fluoroscopy, film radiography, computed tomography, direct radiography. Tomography: Principles of computer tomography, CT Scanner, PET, SPECT, Ultrasound CT Scan, Optical Tomography, 3D Tomography.

REFERENCES

1. Hendee, W.R. and Ritenour, E.R., 2003. Medical Imaging Physics, 4th-ed, Wiley-Liss, Inc., New York.
2. Moores, B.M., Parker R.P., and Pullan B.R. (Editors), 1980, Physical Aspects of Medical Imaging, John Wiley & Sons, New York.

3. Callinan, Jr., J.J. (Editor), 1980, Radiography in Modern Industry, Eastman Kodak Company, Rochester, New York.

MFF 5873 DIGITAL IMAGE

MFF 5873 *Digital Image*

(3 Credits of Compulsory Course Odd Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this course, students are able to:

CO. 1	Explain Digital Image: Digital Image, Image Sampling, Digitization Process, Digital camera;
CO. 2	Explain Image Quality: Brightness, Contrast, Sharpness, Standard Deviation, Statistical Error, Image Correlation. ; Image Processing Fundamentals: Histogram Enhancement,
CO. 3	Explain Point Enhancement, Spatial Filtering, Frequency Filtering; Image Presentation: 2D Image Image, 3D Image,
CO. 4	Explain Image Transformation; Image Analysis: Calibration, Spatial Position, time-lapsed,
CO. 5	Explain and use: Geometric Dimensions; Software Package: ImageJ.

SYLLABUS

Digital Image: Digital Image, Image Sampling, Digitization Process, Digital Camera; Image Quality: Brightness, Contrast, Sharpness, Standard Deviation, Statistical Error, Image Correlation. Image Processing Fundamentals: Histogram Enhancement, Point Enhancement, Spatial Filtering, Frequency Filtering; Image Presentation: 2D Image Imagery, 3D Imagery, Image Transformation; Image Analysis: Calibration, Spatial Position, Time-Lapsed, Geometric Dimensions; Software Package: ImageJ.

REFERENCES

1. Vernon, D., 1991, Machine Vision: Automated Visual Inspection andRobot Vision, Prentice-Hall International Ltd, UK, Ch. 1 - Ch. 7.
2. Gonzales, R.C. and Woods R.E., 2000, Digital Image Processing, PrenticeHall, New Jersey.
3. Phillips, D., 1994. Image Processing in C, R&D Publications, Inc., Lawrence,Kansas.
4. Toriwaki, J. and Yoshida H., 2009. Fundamentals of Three-DimensionalDigital Image Processing, Springer-Verlag London Ltd, London.

MFF 5811 UJI TAK RUSAK

MFF 5811 *Nondestructive Testing*

(2 Credits of Elective Course Odd Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this course, students are able to:

CO 1. Explain the history of NDT, Physics concepts, application context, NDT applications, and benefits of NDT.

CO 2. Explain NDT for material testing. NDT for Object Defect test. Visual Testing: 2D Digital Camera, 3D Stereo Camera, Microscope, Timelapse Method, Panoramic Method.

CO 3. Explain Liquid Penetrant Testing: Penetrant materials, Application methods, Scanning and analysis. Magnetic Particle Testing: Magnetization, Magnetic testing, Application methods, Scanning and analysis.

CO 4. Explain Eddy Current Testing, Acoustic and Ultrasonic Testing, Thermography and InfraRed Testing, Radiography Testing, Tomography Testing, NDT Business and NDT Research and Development Prospects.

SYLLABUS

NDT history, Physics concepts, application context, NDT applications, and benefits of NDT. NDT for a material test. NDT for Object Defect test. Visual Testing: 2D Digital Camera, 3D Stereo Camera, Microscope, Timelapse Method, Panoramic Method. Liquid Penetrant Testing: Penetrant materials, Application methods, Scanning, and Analysis. Magnetic Particle Testing: Magnetization, Magnetic testing, Application methods, Scanning, and Analysis. Eddy Current Testing, Acoustic and Ultrasonic Testing, Thermography and InfraRed Testing, Radiography Testing, Tomography Testing, NDT Business, and NDT Research and Development Prospects.

REFERENCES

1. IAEA, 1999. Non-destructive Testing: A Guidebook for Industrial Management and Quality Control Personel. Training Course Series No. 9, IAEA Vienna.
2. Hellier, C.J., 2003. Handbook of Nondestructive Testing. McGraw-Hill, New York.
3. Ida, N. and Meyendorf, N., 2019. Handbook of Advanced Nondestructive Evaluation, Springer, Cham. DOI https://doi.org/10.1007/978-3-319-26553-7

MFF 5872 MAGNETIC RESONANCE IN MEDICAL PHYSICS

MFF 5872 *Magnetic Resonance in Medical Physics*

(2 Credits of Elective Course Even Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this course, students are able to:

CO. 1 Understand magnetic resonance and its classification.

CO. 2 Understand the NMR superfine spectrum analysis method.

CO. 3 Understand how the NMR spectrometer and its instrumentation work.

CO. 4 Understand the application of NMR to MRI for tissue image optimization.

CO. 5 Use magnetic resonance knowledge for Medical Physics research.

SYLLABUS

Magnetic resonance is related to the existence of NMR (Nuclear Magnetic Resonance) and ESR (Electron Spin Resonance) spectroscopy, also the development of NMR technology in the form of MRI (Magnetic Resonance Imaging). The basis of NMR spectroscopy; NMR spectroscopy: Zeeman's breakdown, exemplary spectrum, and super-fine spectrum. NMR spectrometer, instrumentation systems, methods of use, and analytical techniques. Several scientific cases are discussed based on NMR spectroscopy. MRI technology and history of development. MRI working principles, instrumentation systems, imaging techniques, SOPs for use, and safety dynamics,

REFERENCES

1. Brown, M.A. & Semelka, R.C., 2003: MRI (basic principles and application), 3th edition, Wiley-Liss, New Jersey.
2. Hendee, W.R. & Ritenour, E.R., 2002: Medical Imaging Physics, 4th edition, Wiley-Liss, New York.
3. Jati, B.M.E. & Utomo, B.A.S., 2009: Instrumentasi dan Analisis Resonansi Magnetik NMR, monograf program doktor ilmu Fisika, Departemen Fisika FMIPA UGM, Yogyakarta.
4. Schellart, N.A.M., 2008: Compedium of Medical Physics, Medical Technology and Biophysics, 2nd edition, Dept. of Medical Physics, University of Amsterdam, Amsterdam.
5. Westbrook, C., 2003: MRI at a Glance, 2nd edition, Blackwell Science Ltd., Oxford.

MFF 5875 THREE DIMENSIONAL IMAGING

MFF 5875 *Three Dimensional Imaging*

(2 Credits of Elective Course Even Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this course, students are able to:

CO. 1 Explain the history of 3D imaging, development, and application trends. 3D Imaging applications in production, disaster mitigation, health, safety, defence, and environmental industries.

CO. 2 Explain Imaging techniques: photography, radiography, laminography, shearography, and optical coherence imaging. Geometry projection and 3D presentation.

CO. 3 Explain Photostereography: Stereo camera, anaglyph. 3D Morphology: face recognition and face morphology.

CO. 4 Explain Holography. 3D CT and Multi-slice CT. Structure Light Technique, Time of Flight Application, Sheet of Flight Application. Research and Development Trends and 3D Imaging Innovations.

SYLLABUS

The history of 3D imaging, development trends, and application trends. 3D Imaging applications in production, disaster mitigation, health, safety, defence, and environmental industries. Imaging techniques: photography, radiography, laminography, shearography, optical coherence imaging. Geometry projection and 3D presentation. Photostereography: Stereo camera, anaglyph. 3D Morphology: face recognition and face morphology. Holography. 3D CT and Multi-slice CT. Structure Light Technique, Time of Flight Application, Sheet of Flight Application. Research and Development Trends and 3D Imaging Innovations.

REFERENCES

1. Zhang S., 2013. Handbook of 3D Machine Vision: Optical Metrology and Imaging, 1st-ed, CRC Press. DOI: https://www.routledgehandbooks.com/doi/10.1201/b13856-4
2. Distante A and Distante C, 2020. Handbook of Image Processing and Computer Vision, Vol 3: From Pattern to Object. Springer, Cham. DOI: https://doi.org/10.1007/978-3-030-42378-0

ELECTIVE COURSES
KBK MATERIAL PHYSICS

MFF 5071 INSTRUMENTASI FISIKA

MFF 5071 *Physics of Instrumentation*
(3 Credits of Compulsory Course Odd Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this courses, students are able to:

CO. 1 Shows the relationship between static and dynamic traits in a measurement system.
CO. 2 Describe various types of sensors and transducers based on physical and chemical quantities.
CO. 3 Distinguish between analog and digital electronics in measurement systems.
CO. 4 Describe the model of the interaction of sensors and the environment.

SYLLABUS

A review of the basics of measurement. Static and dynamic disposition of measurement systems. Standards and Calibration. Analysis of uncertainty. Sensors and transducers: Types of sensors and transducers, massive physical and chemical multiplication. Analog electronics in the measurement system. Digital electronics in measurement systems. Elaboration of the model of interaction between the sensor and its environment. Intelligent sensors. The design of the measuring instrument.

REFERENCE

Placko, D., 2007, Fundamentals of instrumentation and measurement, ISTE Ltd.

MFF 5412 APPLIED ELECTROMAGNETICS

MFF 5412 *Applied Electromagnetics*

(3 Credits of MKP Even Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this courses, students are able to:

- CO 1. Understanding complex vectors, Maxwell's equations, Maxwell's equations are dynamic in a medium.
- CO 2. Understand electromagnetic (EM) waves of uniform fields, polarization, reflection and transmission of waves.
- CO 3. Understand waveguides and resonators, transmission lines, and antennas.
- CO 4. Understand the topic of special topics regarding waves, scattering, Fourier optics, and holography.
- CO 5. Understanding the Gaussian beam and the Doppler effect, electromagnetic waves in an isotropic non-isotropic medium.

SYLLABUS

Complex vectors and their use in the presentation and solving of Dynamic Maxwell equations in a medium, AC electrical circuits, electromagnet (EM) waves of uniform planes, reflection and transmission of waves in dielectrics and conductors, waveguides and resonators, transmission lines, antennas, special topics regarding waves: scattering, Fourier optics and holography, The Doppler effect and EM waves in a non-isotropic medium.

REFERENCES

1. Shen, L.C., dan Kong, J.A. (terjemahan, Iwa Garniwa), 2001, Aplikasi Elektromagnetik, Jilid 1 dan 2, Penerbit Erlangga, Jakarta.
2. Ramo, S., Whinnery, J.R., dan van Duzer, T., 1994, Fields and Waves in Communication Electronics, John Willey & Son, New York.

MFF 5601 FISIKA MATERIAL MAMPAT LUNAK

MFF 5601 *Soft Condensed Matter Physics*

(3 Credits of Compulsory Course Odd Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this courses, students are able to:

- CO 1. Understand Fundamental Materials, Basic of Liquid Crystals, Surface Anchoring, Alignment, Confinement.
- CO 2. Understand Elastic Properties, Freedericksz Transitions, Optical Properties.
- CO 3. Understand Liquid Crystal Elastomers.
- CO 4. Understand the basic concepts of polymers and their classification.
- CO 5. Understand various techniques in polymerization, their characterization (morphology and structure), mechanical and rheological properties.

SYLLABUS

Introduction to the physics of soft compressed materials, phases and structures of liquid crystals. Physical and chemical properties of liquid crystals. An explanation of the types of liquid crystals. The optical and electrical effects of liquid crystals. Application of liquid crystal technology in everyday life. Introduction to polymers and properties of polymer molecules, The concept of ideal chains, the distribution of segments on polymers, radius of gyration, non-ideal chains, effects of solvent, thermodynamic properties of polymer solution and application of polymers in everyday life.

REFERENCES

1. S. Chandrasekhar, Liquid Crystals, 2nd Edition, Cambridge UniversityPress, Cambridge, 1977.
2. P. G. de Gennes and J. Prost, The Physics of Liquid Crystals, OxfordScience Publications, 1993.
3. M. Doi, Introduction to Polymer Physics, Oxford University Press, Oxford, 1997.
4. M. Doi and S. F. Edwards, The Theory of Polymer Dynamics, Oxford University Press, Oxford.
5. Warner and E. M. Terentjev, Liquid Crystal Elastomers, Oxford University Press, Oxford, 2003.

MFF 5611 CRYSTAL PHYSICS

MFF 5611 *Crystal Physics*

(3 Credits of Compulsory Course Odd Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this courses, students are able to:

- CO 1. Determine the types of characters in the research material and the research process's result.
- CO 2. Choose the method needed to find out in detail information about the character of a material.
- CO 3. Anticipate the condition of the material whose properties will be known.
- CO 4. Analyze the results shown by the characterization support tool.

SYLLABUS

Introduction to Crystal Structure, Vibrations in Crystals and Bonds in Crystals, Reciprocating And Brillouin Zones, Symmetry in Crystals: Bravais Kekisi Translation Group, Point and Space Group. Crystal math: Tensor and its Rules of transformation. Crystal Equilibrium Properties: Magnetic Susceptibility and Electrical Chemigativity, Thermal Expansion, Piezoelectricity and Elasticity. Crystal Transport Properties: Thermal and Electrical Conductivity. Optics on Crystals: Double-bias, electro-optical effects, and photo elastics. Summary of Aspects of Crystal Physics Experiments.

REFERENCES

1. Nye, J.F, 1985, Physical Properties of Crystals, Clarendon Press, Oxford,UK.
2. Verma, A.R dan Srivastava, O.N., 1982, Crystallography for Solid StatePhysics, WilleyEastern, New Delhi, India.

3. Lovett, D.R., 1980, Tensor Properties of Crystals, Adam Hilger, Bristol, UK.

MFF 5617 NANOPHYSICS

MFF 5617 *Nanophysics*

(2 Credits of Elective Course Odd Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this courses, students are able to:

CO 1. Understand the aspects of physical science that support nanotechnology and understand its application in various fields.

CO 2. Understand the basics of nanophysics and the properties of materials in nanosystems.

CO 3. Understand the application of nanophysics, how to fabricate nanomaterials and how to characterize nanomaterials.

CO 4. Understand scientific articles related to nanomaterials.

SYLLABUS

Introduction to the concept of nanoscience and nanotechnology, the concept of size-dependent (Bulk Material and Film), Summary of the concept of the physics of compressed substances in nanosystems (Meeting states, electronic structures, phonons, Joint Density of States), physical studies of nanostructures such as quantum dots, quantum wells (quantum wells), quantum wires, nanoparticles, nanocrystals (nanocrystals) and Heterojunction systems. Load transport of nanosystems: Landauer-Buttiker formalism, Tunneling current, Electron Localization, Weak localization, anti-weak localization, Quantum Hall Effect. Nano physical System Applications: nanoelectronic semiconductors (MOSFETs, CMOS), nanoparticle semiconductors, two-dimensional Electron Gas (2DEG) heterojunctions, Carbon Nanoribbons Systems, Carbon Nanotubes, Self Assembly Molecules (SAM), Bionanotechnology, molecular motors.

REFERENCES

1. Douglas Natelson, Nanostructures and Nanotechnology, Cambridge University Press, 2015. (e-book is available).
2. Vladimir V. Mitin, Dimitry I. Sementsov, Nizami D. Vagidov, QuantumMechanics of Nanostructures, Cambridge University Press, Cambridge UK, 2010 (e-book is available).
3. Supriyo Datta, Electronic Transport in Mesoscopic System, CambridgeUniversity Press, Cambridge UK, 1995 (e-book is available).
4. Hari Singh Nalwa, Nanostructured Materials and Nanotechnology, Academic Press, California USA, 2002 (e-book is available).

MFF 5701 CONDENSED MATTER PHYSICS

MFF 5701 *Condensed Matter Physics*
(3 Credits of Compulsory Course Odd Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this courses, students are able to:

- CO 1. Formulate and describe (to describe) the symptoms of physics that are being studied and reveal important information contained in the physics problem through various tricks or specific mathematical procedures and utilize various approach steps (approximations).
- CO 2. Pay attention to physics problems in detail, analyze problems and build arguments logically and carefully.
- CO 3. Tracing physics problems from various sources and references to gain understanding for important information.
- CO 4. Solving a problem with well-defined solutions, formulating a problem carefully and trying other approaches in an effort to improve the solution of a challenging problem.

SYLLABUS

A summary of the basic concepts of quantum mechanics and quantum statistics in a system of compressed substances. Fundamental topics in FZM: bonding in atoms, molecules, and compressive substances; energy and potential; the structure of the compressed substance; electronic structure of the compressed substance; mean-field theory; critical phenomena; elementary excitation in compressed substances is associated with the thermal and electromagnetic properties of compressed substances, the topology character of the material, superconductivity.

REFERENCES

1. P M Chaikin, T C Lubensky, 1995, Principles of Condensed Matter Physics,Cambridge University Press, Cambridge, UK
2. Feng Duan, Jin Guojun 2005, Introduction to Condensed Matter Physics,World Scientific Publishing Co., Singapore
3. Michael P Marder, 2010, Condensed Matter Physics, second edition, JohnWiley & Sons, New Jersey, USA.

MFF 5701 PHYSICS OF ELECTRONICS MATERIALS

MFF 5701 *Physics of Electronics Material*
(3 Credits of Compulsory Course Odd Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this courses, students are able to:

- CO 1. Understand the electronic properties of materials (both semiconductor and amorphous) is based on analytical skills based on the fundamental concepts of electron characteristics in solids, including transport, thermal, and optical characteristics.

CO 2. Solve problems with structured solutions (well-defined solutions) in electronic material systems.

SYLLABUS

Electron wave properties, Schrodinger equations, Schrodinger game solving, Energy Band theory in crystals, electrons inside crystals, Electron conductivity inside metals and alloys, semiconductors, Electron conductivity inside ceramics and material amorphous, optical properties in atomic theory, Quantum mechanics treatment for optical properties, fundamental thermal properties, thermal conductivity, heat capacity, thermal expansion.

REFERENCE

Hummel, Rolf E. 1985, Electronic Properties of Materials (An Introduction for Engineers).

MFF 5711 COMPUTATIONAL OF MATERIAL DESIGN

MFF 5711 *Computational of Material Design*

(3 Credits of Compulsory Course Odd Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this courses, students are able to:

CO 1. Formulate, model, and design material systems along with material characteristics (electronic, optical, magnetic, topological, etc.), also reveal essential information through specific mathematical procedures and computational algorithms.

CO 2. Solve a problem with a structured solution (well-defined solutions) in the material system.

CO 3. Apply various forms of visualization, graphics, or simulations through computer assistance and the use of appropriate software, programming languages, and packages or numerical tools (numerical tools) to solve problems in material systems.

SYLLABUS

Quantum mechanics of multiple particles, variational methods, Hartree-Fock method, Functional Theory of Density, Periodic Structure and wave base plane, Molecular Dynamics Simulation, calculation of optimization of geometric structures: surface, interface, and defect system, calculation of the electronic structure of materials, calculation of magnetic properties of materials, calculation of optical properties of materials, calculation of material topology properties, Hands-on and case studies.

REFERENCES

1. David Sholl and Janice A. Steckel, 2011, Density Functional Theory: A Practical Introduction, John Wiley & Sons, USA.
2. F. Giustino et.al., 2014, Materials modelling using density functional theory : properties and predictions, Oxford University Press, , Oxford, UK.

3. Richard LeSar, 2013, Introduction to Computational Materials Science, Fundamentals to Applications, Cambridge University Press, Cambridge, UK.

MFF 5750 KEMAGNETAN ZAT MAMPAT

MFF 5750 *Magnetism in Condensed Matter*

(3 Credits of Elective Course Even Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this courses, students are able to:

- CO 1. Understand the nature of magnetism in materials and the mechanism of their occurrence.
- CO 2. Understand the magnetic interactions in materials and the classification of materials from the aspect of magnetism.
- CO 3. Understand and conduct research in the field of magnetic materials, from the manufacturing process to characterization to determine the magnetic properties of materials.

SYLLABUS

Origin of Magnetism, Introduction and Classification of Magnetic Materials, Diamagnetic, Ferromagnetic, Paramagnetic, Antiferromagnetic, Magnetic Thermodynamics, Magnetic Interactions, Magnetocrine Anisotropy, Crystal Fields as well as Their Application in Magnetic Systems. Molecular Fields: Exchange Power and Molecular Fields, in Ferromagnetism, Antiferromagnetism and Ferrimagnetism, Cooperative Phenomena: Quantum Field and Spin Wave Theory, Summary of Experimental Aspects of Solids Magnetism, Methods of Measurement and Characterization of Magnetic Properties, such as Vibrating Sample Magnetometer (VSM), Torque Magnetometer, Magnetic Force Microscopy (MFM).

REFERENCES

1. Stephen Blundell, 2001, Magnetism in Condensed Matter, OUP Oxford, USA.
2. Craik, D., 1995, Magnetism: Principles and Applications, John Willey &Sons, Chischester, UK.
3. Chakravarty, A.S., 1980, Introduction to the Magnetic Properties of Solids,John Willey & Sons, New York, USA.

.

MFF 5780 CONDENSED MATTER OPTICS

MFF 5780 *Condensed Matter Optics*

(3 Credits of Elective Course Even Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this courses, students are able to:

CO 1. Formulate and describe the physical phenomena being studied and reveal vital information in the physics problem through various tricks or specific mathematical procedures and utilizing different approximations.
CO 2. Pay attention to physics problems in detail, analyze issues, and build arguments logically and carefully.
CO 3. Research physics problems from various sources and references to understand important information.
CO 4. Solve issues with structured solutions (well-defined solutions), formulate a problem carefully, and try other approaches to improve the solution of a challenging problem.

SYLLABUS

Introduction of fundamental optical properties of materials: the theory of propagation of electromagnetic waves in materials, optical constants, refractive indices, dispersions. Basic optical studies for conductor materials, insulators, and semiconductors. The optical properties of several compressed materials: photonic crystals, surface plasmons, metamaterials, spintronic materials, organic semiconductors, magneto-optics, thin films, and exciton. Nonlinear optical properties of the material are compressed.

REFERENCES

1. Jai Singh, 2006, Optical Properties of Condensed Matter and Applications,John Wiley & Sons, Chichester, England, UK.
2. Joseph H Simmons, Kelly S Potter, 2000, Optical Materials, Academic Press, San Diego, USA.
3. Yoshinobu Aoyagi, Kotaro Kajikawa (editors), 2013, Optical Properties of Advanced Materials, Springer-Verlag Berlin, Heidelberg
4. Mark Fox, 2001, Optical Properties of Solids, Oxford University Press,Oxford, UK.

MFF 5814 MATERIAL CHARACTERISATION METHODS

MFF 5814 *Material Characterisation Methods*

(3 Credits of Elective Course Even Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this courses, students are able to:

CO 1. Determine the types of characters in the research material and the research process's result.
CO 2. Choose the method needed to find out in detail information about the character of a material.
CO 3. Anticipate the condition of the material whose properties will be known.
CO 4. Analyze the results shown by the characterization support tool.

SYLLABUS

Introduction to material methods and analysis; molecular spectrometry: UV-visNIR, Raman, Nuclear Magnetic Resonance (NMR), mass spectroscopy (MS); atomic spectroscopy: Atomic Absorption Spectrometry (AAS) and Atomic Fluorescence Spectrometry (AFS), instruments such as Gas Chromatography (GC), High-Performance Liquid Chromatography (HPLC), Electrophoresis; image instruments: Optical Microscopy, Confocal Microscopy, Electron Microscopy (Scanning Electron Microscopy or SEM, Transmission Electron Microscopy or TEM, Scanning Probe Microscopy or SPM, Scanning Tunnelling Microscopy (STM), Atomic Force Microscopy (AFM), electrochemical instruments: Potentiometry, Voltammetry, Conductimetry; Thermogravimetric Analysis (TGA), Differential Scanning Calorimetry (DSC), X-ray Diffraction (XRD), Angle-resolved photoemission spectroscopy (ARPES), X-ray Photoemission spectroscopy (XPS), Vibrating-sample magnetometer (VSM).

REFERENCES

1. McMohan, G., 2007: Analytical Instrumentation: A Guide to Laboratory, Portable and Miniaturized Instruments, John Wiley & Sons Ltd, England.
2. Skoog, D.A. dan West, D.M., 1980: Principles of Instrumental Analysis,Sounders College, Philadelphia.

MFF 5855 SPINTRONICS

MFF 5853 *Spintronics*

(3 Credits of Compulsory Course Odd Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this courses, students are able to:

- CO 1. Formulate and describe the physical phenomena being studied and reveal vital information in the physics problem through various tricks or specific mathematical procedures and utilizing different approximations.
- CO 2. Pay attention to physics problems in detail, analyze issues, and build arguments logically and carefully.
- CO 3. Research physics problems from various sources and references to understand important information.
- CO 4. Solve issues with structured solutions (well-defined solutions), formulate a problem carefully, and try other approaches to improve the solution of a challenging problem.

SYLLABUS

Quantum Theory on Spin, Spin-Orbit Interaction, Spin Relaxation, Review of Spin-Orbit Interaction on Crystal Systems, Spin-Orbitronics Systems, Magnetic Skyrmion on 2D Materials, Special Topics on Orbitronic Systems, Spin Polarization Phenomena, Effects of Spin Transfer Torque and Spin Injection, Soft and Hard Magnetic, Magnetic Anisotropy, Magnetic Domains and Domain Walls, GMR and Spin-Dependent Scattering Transport, TMR and and Spin-Dependent Tunneling Transport, Spin Transistor, MRAM and Magnetic Storage, spin thermoelectricity.

REFERENCES

1. Coey, J.M.D., 2010, Magnetism and Magnetic Material, Cambridge Univ.Press.
2. Heck, C., 1974, Magnetic Material and Their Application, Newnes-Butterworth.
3. Lombardi, G.C. dan Bianchi, G.E., 2009, Spintronics: Materials, Applications and Devices, Nova Science Pub Inc.

MFF 5870 BIOMATERIAL PHYSICS

MFF 5870 *Biomaterial Physics*

(2 Credits of Elective Course Even Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this courses, students are able to:

- CO 1. Understand Introduction to Materials Physics; Introduction to Biomaterial and Biochemistry Physics; Synthesis of Hydroxyapatite (HA) and Carbonate Hydroxyapatite.
- CO 2. Understand Biomaterial Characterization: SEM-EDS; Biomaterial Characterization: XRD and FTIR; Biocomposite and Scaffold Biomaterial.
- CO 3. Understand Applications of Biomaterials in Tissue Engineering.
- CO 4. Understand the variety of polymer-based biomaterials and their application in the medical field as implants.
- CO 5. Understand the interaction of biomaterials with tissues and how to test biomaterials (biological tests, physics and so on).

SYLLABUS

The introduction of organic materials with an emphasis on the science of polymers, the structure, processing, properties and use of organic materials, including polymers, biomacromolecules and organic materials with small molecular sizes. Topics covered include Synthesis and processing of polymers, structure and characteristics of polymers, Properties and applications of polymers and advanced organic materials. In particular, it can choose the right way of Synthesis and processing strategy to prepare some polymers in general. Predict the properties of polymers and molecular materials based on knowledge of their structure and morphology. Choosing the suitable polymer for particular application based on the necessary properties.

REFERENCES

1. Paul C. Painter & Michael M. Coleman, 2009, Essentials of Polymer Science and Enginee- ring, DEStech Pub Inc.
2. Robert J. Young, Peter A. Lovell, 1991, Introduction to Polymers, Springer US.

ELECTIVE COURSES
KBK GEOSCIENCE

MFF 5052 TIME SERIES ANALYSIS

MFF 5052 *Time Series Analysis*
(3 Credits of MKP Even
Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this courses, students are able to:

CO 1. Understand and model discrete signals and systems in the time domain.
CO 2. Understand and model discrete signals and systems in the frequency domain.

CO 3. Designing FIR and IIR filters.

SYLLABUS

The relationship between inputs and outputs in the frequency and time domain, convolution, correlation, Fourier series, digital Fourier transformation (DFT), rapid Fourier transformation (FFT), and digital filter theory. Z-transformation: system switching function, reverse Z-transformation, and system flow chart.

REFERENCES

1. Brigham, E.O., 1974, The Fast Fourier Transform, Prentice Hall, Inc.
2. Brustle, W., 1987, Advanced Digital Signal Processing, Lab. Geofisika, FMIPA UGM.
3. Proakis, J.G., and Manolakis, D.G., 1993, Digital Signal Processing: Principles, Algorithms, and Applications, McMillan.
4. Alkin, O., 1994, Digital Signal Processing: A Laboratory Approach usingPC-DSP, Prentice Hall.

MFF 5073 DATA ACQUISITION SYSTEM

MFF 5073 *Data Acquisition System*
(3 Credits of Compulsory Course
Odd Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this courses, students are able to:

CO 1. Mastering the basic fields of physical science, which include the study of electrodynamics, mechanics, classical, and quantum mechanics.
CO 2. Mastering and being able to apply one of the fields of advanced physical sciences.
CO 3. Mastering the ability to study a problem in a field of physics through research.

SYLLABUS

Introduction to data acquisition on the PC (PC as a data acquisition platform and its software), the basics of data sampling (sensors and interfaces, sampling, noise, and filters), I/O techniques (interrupt systems, data transfer, parallel buses, and serial communication), data interpretation (interpolation and linearization), examples of data acquisition.

REFERENCES

1. Barrett, S. F. dan Pack, D.J., 2008: Atmel AVR Microcontroller Primer: Programming and Interfacing, Morgan & Claypool Publishers.
2. James, K., 2000: PC Interfacing and Data Acquisition, Newnes, LinacreHouse, Jordan Hill, Oxford.

MFF 5831 ADVANCED CONTINUUM MECHANICS

MFF 5831 *Advanced Continuum Mechanics*

(3 Credits of Compulsory Course Odd Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this courses, students are able to:

- CO 1. Understand the basic concepts of the strain–stress relationship.
- CO 2. Understand the deformation concept in an object that experiences strain stress in 3D space and in time change variables.
- CO 3. Understand the concepts of conservation of mass, momentum, and energy.
- CO 4. Understand the concept of Newtonian and Non-Newtonian fluid flow, both compressible and incompressible.
- CO 5. Understand the concepts of linear and non-linear elasticity in a fluid flow.

SYLLABUS

The principles of stress, deformation, and motion, fundamental laws and equations in mechanics, dynamics of linear elastic solids, classical fluids, fluid dynamics in geophysics, computational mechanics of continuous mediums, and nonlinearity of earth materials.

REFERENCES

1. W WILLIAM I. NEWMAN, 2012, continuum mechanics in the earth sciences
2. A.B Bathia dan R.N. Singh, 1978, Mechanics of Deformable Media.
3. George E. Mase, 1970, Schaum's Outline of Continuum Mechanics.

MFF 5881 ADVANCED GEOTHERMAL EXPLORATION

MFF 5881 *Advanced Geothermal Exploration*

(2 Credits of Elective Course Odd Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this courses, students are able to:

CO 1. Know the elements of geothermal systems and geophysical methods used in geothermal exploration.
CO 2. Build design surveys and conduct data collection, processing, modeling, and interpretation in the context of geothermal exploration.

SYLLABUS

Geothermal exploration includes about (1) geological control of the distribution and nature of geothermal systems; (2) the main types of geothermal systems and how energy is harnessed using the latest technology; (3) the potential of geothermal resources that can provide useful energy; and (4) geophysical methods that can be used for potential geothermal mapping. Geological influence on character and reservoir volume; and how to design surveys, conduct data collection, process modeling, and interpret geophysical data for geothermal exploration.

REFERENCES

1. Browne, P.R.L., 1978. Hydrothermal alteration in active geothermal fields.Annual Reviews Earth Planetary Sciences, 6, 229-250.
2. Browne, P.R.L., 1998. Hydrothermal alteration in New Zealand geothermal systems. In: Arehart&Hulston (Eds.), Water-Rock Interaction, Balkema, Rotterdam.
3. Browne, P.R.L., Rodgers, K.A.,2006. Occurrence and significance of anomalous chloride waters at the Orakeikorako geothermal field, Taupo Volcanic Zone, New Zealand.Geothermics, 35, 211-220.
4. Giggenbach, W.F., Glover, R.B., 1992. Tectonic regime and major processes governing the chemistry of water and gas discharges from the Rotorua geothermal field, New Zealand, Geothermics, 21, 121-140.
5. Giggenbach, W.F., Minissale, A.A.,Scadriffio, G., 1988. Isotopic and chemical assessment of geothermal potential of the Coli Albani area, Latium region, Italy. Applied Geochemistry, 3, 475-486.
6. Giggenbach, W.F. 1992. Isotopic shifts in waters from geothermal and volcanic systems along convergent plate boundaries and their origin. Earth and Planetary Science Letters, 113, 495 – 510.

MFF 5891 DISASTER MITIGATION

MFF 5891 *Disaster Mitigation*
(2 Credits of Elective Course
Odd Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this courses, students are able to:

CO 1. Students can make disaster risk map.
CO 2. Analyzing the risk of a disaster.
CO 3. Create a natural disaster mitigation strategy using geophysical methods to minimize risks.

SYLLABUS

The material in this lecture includes 1) efforts to reduce the risk of earthquakes, tsunamis, volcanic eruptions, floods, landslides, and other natural disasters through measurement, mapping, development of simulation software, and another method.; Perform analysis and calculate disaster risk. 2) Develop a disaster mitigation strategy, for example, by developing an early warning system, socialization, training, and so on. After taking this course, students are expected to be able to analyze the risk of a disaster, create natural disaster mitigation strategies using geophysical methods to minimize risks, and create disaster-prone maps.

REFERENCES

1. Spence, R.J.S., Coburn, A.W., Pomonis, A., and Sakai, S., 1992, Correlation of building damage with strong ground motion, in World Conference of Earthquake Engineering, 10th, Madrid, Spain, Proceedings, v. 1: p. 551-557.
2. Anonim, Buku Saku Mitigasi Bencana dari BPBD Bantul Yogjakarta.

MFF 5910 PHYSICAL GEOLOGY

MFF 5910 *Physical Geology*

(2 Credits of Elective Course Even Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this courses, students are able to:

- CO 1. Understand the definitions of geology and physical geology, the development of theory of continental drift, sea floor spreading, plate tectonics, the physical properties of Earth (gravitational force, magnetism of earth, Earth's revolutions, theory of isostasy).
- CO 2. Understand rock-forming minerals and radioactive properties of minerals, magma, types of igneous rocks, and pyroclastic rocks products of volcanic eruptions.
- CO 3. Understanding clastic and non-clastic sedimentary rocks, metamorphic rocks, weathering of rocks (weathering), and stratigraphy.
- CO 4. Understand the geology cycles (hydrogeological, rock, carbon cycle), the geology of structures and landscapes, tectonic extensions, compression, and transformation.
- CO 5. Understand earthquakes and plate tectonics, geology, and natural resource exploration.

SYLLABUS

Physical Geology Course studies the concepts of geology, the physical properties of the planet earth and the constituent materials of the earth's body, and the processes that occur in the earth's crust with an emphasis on tectonics, plate tectonic theory, the formation of the earth's crust, petrology and stratigraphy, geomorphology, geological structure, geological hazards, and the presentation of geological data in geological maps.

REFERENCES

1. Sanders, J.E., 1981, Principle of Physical Geology, John Willey & Sons.
2. Hamblin, W.K., 1982, The Earth’s Dynamic System, Burgess Publishing Co.,

Minnesota.

MFF 5911 PHYSICS OF THE EARTH

MFF 5911 *Physics of the Earth*
(3 Credits of Compulsory
Course Odd Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this courses, students are able to:

CO 1. Explain views/thoughts/explanations about the structure and internal dynamics of the earth.
CO 2. Identify problems related to the physics of the earth.
CO 3. Analyze problems related to earth physics.
CO 4. Explain the concept of solving problems related to the physics of the earth.

SYLLABUS

The universe, galaxies, its layout, the earth, and its constituent compositions. Radioactivity, determination of the absolute age, and age of the earth. Evidence of the earth's evolutionary history, shape, rotational motion, and gravity. Rotation, precession, wobble, and gravitational spectators of the earth. Geoids, satellite geoids, elastic, and non-elastic properties of earth rocks. Deformation of the earth's crust and tectonics. Convection motion, crustal stress, and earthquake kinematics. Dynamics of earthquakes and the passage of seismic waves. The earth's internal structure is based on seismology, strain, and equations of high-pressure states. The thermal condition of the earth and the thermal flux on the surface of the earth. The global balance of thermal energy and the earth's fluid convection thermodynamics. The thermal history of the earth and the magnetic field of the earth. Rock magnetization, ancient magnetism, alternative energy sources, and natural variations of the global climate.

REFERENCES

1. Bott, H.G.P, 1981, The Interior of the Earth, John Willey & Sons.
2. Mahasiswa S2-Ilmu Fisika, 2014-2016, Tugas Makalah dan Presentasi.
3. Stacey, Frank D., 1977, Physics of the Earth, John Willey & Sons.
4. Stacey, Frank D., and Davis, M. Paul., 2008, Physics of the Earth, Cambridge University Press.

MFF 5916 ADVANCED ROCK PHYSICS

MFF 5916 *Advanced Rock Physics*
(2 Credits of Elective Course Even
Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this courses, students are able to:

CO 1. Understand and conceptualize the behaviour of rocks on various physical parameters and the relationship between physical parameters of one another.
CO 2. Mastering the basic concepts of rock physical properties and solving problems with rock physical properties in an integrated and comprehensive manner.

SYLLABUS
Basic concepts of rock properties are seen from physical parameters and can solve fundamental problems and problems of rock physical properties in an integrated and comprehensive manner. Matter Physics of rocks as part of earth science. Properties of porosity, permeability, internal surface, and density. Magnetic Properties of Rocks. Radioactivity of Rocks. The elasticity of Rocks. Seismic Wave Attenuation. Thermal Properties of Rocks. Electrical Properties of Rocks. Relationships Between Physical Properties of Rocks.

REFERENCES
1. Schon, J.H., 1998, Physical Properties of Rocks, Pergamon Press.
2. Guegen, Y and Palciauskas, V., 1994, Introduction to the Physics of Rocks,Princeton University Press.
3. Mavko, G, Mukerji, T, and Dvorkin, J., 1999, The rock Physics Handbook. Cambridge University Press.

MFF 5918 VULCANOLOGY
MFF 5918 *Vulcanology*
(2 Credits of Elective Course Even Semester)
PREREQUISITE
None

LEARNING OBJECTIVES
After taking this courses, students are able to:
CO 1. Understand the concept of Earthquakes and Volcanoes.
CO 2. Understand the challenges of research on Volcano-Physics with Geophysical Methods.
CO 3. Master geophysical observation methods for active volcanoes.
CO 4. Apply Mountain Range modeling.
CO 5. Conduct a model of Merapi volcano based on changes in gravity data.

SYLLABUS
1. Nature of volcanism: the location of volcanoes in the world, the type of volcanoes, the frequency of erupting volcanoes, the rise of magma and eruptions, volcanic products and hazards for nuclear facilities, and monitoring of volcanoes.
2. Modern volcanological tools: movement of volcanoes - the moment of deformation to extremes, volcanology in the information age, brief survey reports on volcano monitoring, techniques, the introduction of sensors, and geodesy techniques.
3. Classical survey techniques: Early geodesy surveys, reference and data systems, geodesy networks, trilateration, and triangulation, leveling and tilt-leveling

surveys, Photogrammetry, microgravity surveys, magnetic field measurements.

4. Continuous monitoring with on-site sensors: Seismometer, Tiltmeters, Strain meter, Continuous GPS, some warnings about near-surface deformation sensors, continuous gravimeter observations, and volcanic crater lake descent measurements.
5. Global Positioning System: Global positioning principles, GPS Overview, GLONASS, Galileo, GPS signal structure. GPS receiver. Combination and difference of data, using mathematics: transforming data into multiple positions, Relative position Engineering, CGPS network, data processing, looking into the future.
6. Interferometric synthetic-aperture radar (InSAR): Principles and techniques of radar, Principles of SAR interferometry.

REFERENCES

1. B. Connor, N. A. Chapman, L. J. Connor, 2009, Volcanic And Tectonic Hazard Assessment For Nuclear Facilities Volcanic And Tectonic Hazard Assessment For Nuclear Facilities, Published in the United States of America by Cambridge University Press, New York.
2. Daniel Dzurisin, 2007, Volcano Deformation, Geodetic Monitoring Techniques, United States Geological Survey, Praxis Publishing Ltd, Chichester, UK.

MFF 5925 GEOSCIENCES DATA ANALYSIS AND VISUALIZATION

MFF 5923 *Geosciences Data Analysis and Visualization*

(2 Credits of Elective Course Odd Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this courses, students are able to:

CO 1. Identify and design the most appropriate visualization strategy for geoscience data.

CO 2. Create visualization results using Microsoft Office, Inkscape, Python, R, and Julia.

CO 3. Create spatial data visualizations using Generic Mapping Tool, QGIS, and ArcGIS

SYLLABUS

This course contains visualization techniques and strategies in the field of geoscience. Color selection techniques, strategies, and data representation in geoscience cases. Data visualization using the relevant programming language (Python, R, Julia). Use Generic Mapping Tools (GMT) for spatial visualization of geoscientific data. Data visualization using basic software (Microsoft Office). Techniques and strategies for data representation using ArcGIS and QGIS. Compile images and graphics using Inkscape.

REFERENCES

1. Graser, A. (2016). Learning Qgis. Packt Publishing Ltd.
2. Joshi, A., & Lakhanpal, R. (2017). Learning Julia: Build high-performance applications for scientific computing. Packt Publishing Ltd.
3. Tutorial, G. M. T. (2015). THE GENERIC MAPPING TOOLS.

4. Yim, A., Chung, C., & Yu, A. (2018). Matplotlib for Python Developers: Effective techniques for data visualization with Python. Packt Publishing Ltd. Mahasiswa S2-Ilmu Fisika, 2014-2016, Tugas Makalah dan Presentasi.

MFF 5924 ADVANCED ENVIRONMENTAL GEOPHYSICS

MFF 5924 *Advanced Environmental Geophysics*

(2 Credits of Elective Course Even Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this courses, students are able to:

CO 1. Explain environmental problems, analysis of environmental impacts, and various local, national, and global ecological laws.

CO 2. Master various geophysical concepts or methods in contributing to solving environmental problems.

CO 3. Apply various geophysical methods in solving various environmental problems.

SYLLABUS

Studying the resolution of environmental problems using various geophysical methods, such as gravity, magnetic, geoelectric, electromagnetic, seismic methods, and other methods. The various problems studied are environmental pollution due to volcanic eruptions, earthquakes, tsunamis, floods, landslides, groundwater pollution, electromagnetic wave pollution, seawater intrusion and subsidence, temperature and sound pollution, and vibrations in civil buildings.

REFERENCES

1. Ward, S.H., Editor 1990, Geotechnical and Environmental Geophysics,SEG.
2. Davis, M.L. and Cornwell, D.A., 1991, Introduction to Environmental Engineering, McGraw Hill, Inc.

MFF 5930 ADVANCED SEISMOLOGY

MFF 5930 *Advanced Seismology*

(3 Credits of Elective Course Even Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this courses, students are able to:

CO 1. Conduct statistical studies on earthquake data spatially and temporally.

CO 2. Conduct physical studies (static stress) in earthquake events.

CO 3. Conduct studies (dynamic stress) on earthquake events.

CO 4. Modeling seismic wave using certain software.

CO 5. Have ethics and professional attitudes that are commendable as scientists.

SYLLABUS

Elastic Waves in the Earth: Waves and wave sources: (Wave equations, rheology, boundary terms and initial terms, fundamental settlements, wave sources, scattering effects, seismic wave problems as linear systems Waves in a discrete world: classification of partial differential equations, computational physics, and mesh domains, 1D, 2D, 2.5D, and 3D concepts, the influence of parallel computing on seismology.

Introduction to Numerical Methods in Seismology: The Finite-Difference Method, Pseudo-Spectral Method, Finite-Element Method, Spectral-Element Method, Volume-Finite Method, Volume-Finite-Volume Method, The Discontinuous Galerkin Method. III Application: Application in global seismology and geosciences. Some illustrations of seismological problems in computer code. The challenges of today's seismology and geosciences.

REFERENCES

1. Computational Seismology: A Practical Introduction by Heiner Igel, Oxford University Press 2016.
2. Quantitative Seismology: Theory and Methods, Volumes I and II by KeiitiAki and Paul G. Richards. W. H. Freeman and Co., San Francisco.

MFF 5931 ELECTROMAGNETIC SURVEY

MFF 5931 *Electromagnetic Survey*

(3 Credits of Compulsory Course

Odd Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this courses, students are able to:

CO 1. Apply the science of electricity and electromagnetism with the target of rock electrical materials.

CO 2. Design resistivity and EM surveys.

CO 3. Conduct the acquisition and process of resistivity and EM surveys

CO 4. Synthesize the results of processes related to geological phenomena.

SYLLABUS

Explanation of the basics of theory, instrumentation, data collection, and processing, as well as the interpretation of electromagnetic surveys. Discussion: methods of resistance type, self-potential (SP), magnetic, electromagnetic, TURAM, VLF, and others.

REFERENCES

1. Wait, J.R., 1983, Geo-Electromagnetism, Academic Press.
2. Parasnis, D.S., 1979, Principles of Applied Geophysics, Chapman and Hall.

MFF 5932 POTENTIAL FIELD THEORY

MFF 5932 *Potential Field Theory*

(3 Credits of Elective Couse

Even Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this courses, students are able to:

- CO 1. Understand and master the gravitational field and potential field.
- CO 2. Master the concept of analytical methods for the interpretation of gravitational anomalies.
- CO 3. Solve potential problems and gravitational acceleration.

SYLLABUS

Potential field theory in general, Earth's gravitational field, Earth's magnetic field, gravitational and magnetic survey methods (gravimeter, magnetometer, gravitational and magnetic survey concepts, simplification for modeling purposes), gravitational/magnetic potential, Laplace and Poisson equations, Gauss equations, Stokes equations, and Greens equations. Equivalent stratum, a continuation of the potential field up and down, differentiation of the potential field, development of 2D and 3D multipole gravitational field, 2D and 3D excess mass calculation, 2D and 3D positioning of the center of mass excess, correction in the measurement of the gravitational field, reduction of data from an irregularly distributed topographical plane to a horizontal plane with data distribution in a grid, separation of regional and local effects, a downward continuation of the gravitational field for two- and more-than-two-layer models, depth determination, geoid.

Quantitative interpretation of the gravitational field: excess mass calculation, three-dimensional models, examples of interpretation with multipole expansion three-dimensional and two-dimensional models. Quantitative interpretation of magnetic fields: data correction, reduction to the horizontal plane, magnetic field anomalies, magnetic field continuity, demagnetization, tabular models, polygon models, examples of processing results of aeromagnetic surveys.

REFERENCES

1. Baranov, W., 1975, Potential Fields and Their Transformations in Applied Geophysics, Grebuder Borntraege, Berlin-Stuttgart.

2. Grant, F.S. and West, G.F., 1965, Interpretation Theory in Applied Geophysics, McGraw-Hill.
3. La Fehr, Thomas R., and Misac N. Nabighian, 2012, Fundamentals of Gravity Exploration, SEG, The International Society of Exploration geophysicists.
4. Mahasiswa S2-Ilmu Fisika, 2014-2017, Tugas Makalah dan Presentasi.
5. Telford, M.W., et al, 1976, Applied Geophysics, Cambridge UniversityPress.

MFF 5933 GEOPHYSICS INVERSION

MFF 5933 *Geophysics Inversion*

(2 Credits of Elective Course

Odd Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this courses, students are able to:

CO 1. Understand the inverse theory and examples of Forwarding Problems.
CO 2. Master the concepts of linear algebra and statistics.
CO 3. Master the Inverse Method based on length.
CO 4. Master the linearization of nonlinear problems.
CO 5. Master the eigenvalue problem and singular-value decomposition (SVD).
CO 6. Generalize the measurement quality inversion.

SYLLABUS

Introduction to inversion theory, review of linear and statistical algebra, Inverse method based on length, Linearization of nonlinear problems, eigenvalue problems, decomposition of single values (svd), general inverse and quality measures, general inversion variations. Characterization of inversion problems, linear, discrete inversion problems, nonlinear linearization problems, discrete problems of unclear inversion, regularization, inversion and search of nonlinear parameters, probability inference.

REFERENCES

1. Albert Tarantola, 2005, Inverse Problem Theory and Methods for Model Parameter Estimation, Siam.
2. Robert L. Parker, 1994, Geophysical Inverse Theory,
3. Richard C. Aster, Brian Borchers, 2012, Parameter Estimation and Inverse Problems, Elsevier.
4. Menke, 1989, Geophysical data analysis: discrete inverse theory, AcademicPress.
5. Randall M. Richardson and George Zandt, 2007, Inverse Problems In Geophysics, 2007, Department of Geosciences, University of Arizona, Tucson, Arizona 85721.
6. Scales, J.A., Smith, L. M., dan Treitel, S., 1997, Introductory Geophysical Inverse Theory, Samizdat Press.
7. Snieder R., dan Trampert, T., Inverse Problems in Geophysics, (http://samizdat.mines.edu/snieder tra

MFF 5934 NON-ELECTROMAGNETIC SURVEY

MFF 5934 *Non-electromagnetic Survey*
(2 Credits of Elective Course Even
Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this courses, students are able to:

- CO 1. Understand the basic theory of seismic waves applications.
- CO 2. Understand the basic theory of the gravity of the earth.
- CO 3. Understand and carry out seismic methods acquisition, process, and analysis.
- CO 4. Understand and be able to carry out acquisitions, processes, and analyses of gravity methods.

SYLLABUS

Geophysical survey with gravity, seismic (reflective and refracted) methods, radioactivity, thermometry, basic multi-theory methods, types of exploration goals, instrumentation, data collection procedures, their analysis and interpretation, and examples of their application.

REFERENCES

1. Milson, J, 1995, Field Geophysics, Oxford Univ.Press.
2. Hochstein, M.O., 1982, Introduction to Geothermal, Propecting, GeothermInstitut Univ. of Auckland.
3. Parasnis, D.S., 1979, Principles of Applied Geophysics, Chapman and Hall.

MFF 5935 QUANTITATIVE SEISMOLOGY

MFF 5935 *Quantitative Seismology*
(3 Credits of Compulsory Course
Odd Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this courses, students are able to:

- CO 1. Derive the equation of elastic waves.
- CO 2. Write down wave equations in the chosen computer language.
- CO 3. Solve problems related to elastic waves using a simple computer program.

SYLLABUS

Earthquakes and the theory of elasticity, vibration and seismic waves, green functions, waves in the body of the Earth, surface waves (Rayleigh and Love Waves), surface wave dispersion, reflection, refraction, seismic ray theory (spherical symmetry medium) and its implementation in anisotropy, attenuation, elasticity.

REFERENCES

1. Aki, K. dan Richards, P.G., 1980, Quantitative Seismology, W.H. Freeman.

2. Cervený, V. (2001). Seismic ray theory (Vol. 110). Cambridge: Cambridge university press.
3. Grant, F.S. dan West, G.F., 1985, Interpretation Theory in Applied Geophysics, McGraw-Hill.
4. Stein, S., & Wysession, M. (2009). An introduction to seismology, earthquakes, and earth structure. John Wiley & Sons.

MFF 5936 MINERAL EXPLORATION

MFF 5936 *Mineral Exploration*
(2 Credits of Elective Course
Even Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this course, students are able to:

CO 1. Explains the economic mineralogy of minerals, related to their formation and their discoverability in nature.
CO 2. Describes the application of geophysical methods to mineral exploration.
CO 3. Rewrite, analyze, and deliver a mineral exploration case study.

SYLLABUS

Introduction: Tectonic concepts.

Rocks: Igneous, Sedimentary, Metamorphic.

Minerals: Formation of mineral, physical properties of minerals.

Geophysical survey for minerals: Magnetic, Gravity, Resistivity, Electromagnetic, Polarization Induction, and the problem of integrated geophysical surveys.

REFERENCES

1. Husein S, 2009, Handout Geologi Dasar 2010. Fak. Teknik Geologi UGM.
2. Milsom J, 2003, Field Geophysics, 3rd Ed, John Wiley & Sons Ltd, WestSussex PO19 8SQ, England.
3. Telford, W.M., Geldard, L.P., and Sheriff, R.E, 1990, Applied Geophysics. 2nd Ed, Cambridge Univ Press.

MFF 5937 PETROLEUM EXPLORATION

MFF 5937 *Petroleum Exploration*
(2 Credits of Elective Course
Odd Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this courses, students are able to:

CO 1. Describes the propagation of reflective seismic waves for exploration/study of the existence of natural resources, especially oil and gas.

CO 2. Determine, calculate, analyze, design acquisitions, and know seismic data processing steps.

CO 3. Interpretate seismic data from processing results.

SYLLABUS

The origin of oil and gas and the types of oil and gas traps.

Elements of the seismic survey: Stress and strain, Seismic waves, Body waves, Surface waves, Waves and rays, Seismic wave speed in rocks, and Seismic wave suppression along the wave's trajectory. The trajectory of the wave rays on the layered medium, Reflections, and usual assorted rays at a normal angle of arrival. Reflections and ordinations at the angle of the rays come with oblique, critical bias, and diffraction.

Reflection and ordinary surveys: seismic data acquisition system, seismic and acoustic sources of the spectrum, seismic sensors, recording systems. Reflector seismic surveys: Single flat reflector, Layered flat reflector, inclined reflector, multiple reflecting beam trajectories.

Reflected seismogram: seismic trace, shot gather, CMP gathers. Multi-channel reflective survey design: Vertical and horizontal resolution, detector stretch design, CMP survey, reflective seismic data display.

Time correction on seismic trace: static correction, speed analysis. Seismic data screening: Filter frequency, inversion (deconvolution), filter speed. Migration. 3D seismic survey. Interpret reflective seismic data: Structure analysis, Stratigraphy analysis, Sequence seismic modelling, Seismic attribute analysis.

REFERENCES

1. Sheriff R.E and Geldart L.P., 1995, Exploration Seismology, 2nd Ed, Cambridge.
2. Kearey P., Brooks M., and Hill I., 2002, An Introduction to GeophysicalExploration, 3rd Ed, Blackwell Science Ltd.,

MFF 5939 KULIAH LAPANGAN GEOSAINS

MFF 5939 *Geoscience Field Trip*

(2 Credits of Elective Course

Odd Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this courses, students are able to:

CO 1. Take care of geophysical field survey permits.

CO 2. Understand how to work, maintain, and operate various geophysical equipment in the field.

CO 3. Carry out data acquisition, processing, and interpreting geophysical data (modelling) with gravity methods.

CO 4. Acquire data, process, and interpret geophysical data (modelling) with magnetic methods.

CO 5. Carry out data acquisition, processing, and interpretation of geophysical data (modelling) with geoelectric methods.

CO 6. Carry out data acquisition, processing, and interpretation of geophysical data (modelling) with geo-electromagnetic methods.

CO 7. Acquire, process, and interpret geophysical data (modelling) with seismic methods.

CO 8. Operate various survey support equipment, such as GPS, compass, geological hammer, and reading topographic and geological maps.

SYLLABUS

This Geophysical Field Practice raises one case study using actual field data with the same target. Material:

1. Seismic Methods: a. Conducting field refraction seismic measurements, creating a travel time curve from seismic refraction data, modelling seismic refraction data. b. Conducting micro-seismic measurements in the field, calculating HVSR and PGA (Peak Ground Acceleration) mapping.
2. Gravity Method: perform field measurements with gravimeter tools, reduce and correct gravity data, calculate complete Bouguer anomalies, reduce to flat planes, filter gravity data, and interpret data qualitatively and quantitatively (modelling).
3. Magnetic Method: perform geomagnetic field measurements with a magnetometer, reduce and correct magnetic data, calculate magnetic anomalies, filter magnetic data (continuation), and interpret data qualitatively and quantitatively (modelling).
4. Geoelectric Method: measuring resistivity in both sounding and mapping field, processing pseudo-resistivity data, conducting 1D and 2D modelling of resistivity data.
5. Electromagnetic Method: a. Conducting electromagnetic VLF (Very Low Frequency) field measurements, processing, and interpreting VLF data, both qualitatively and quantitatively. b. Perform CSAMT (Controlled Source Audio Frequency Magnetotelluric) acquisition, processing, and interpretation of CSAMT data, both qualitatively and quantitatively.

REFERENCES

Buku Panduan Praktek Lapangan Geofisika S2, terbitan Lab. Geofisika UGM.

MFF 5880 ADVANCED SEISMIC IMAGING

MFF 5880 *Advanced Seismic Imaging*
(2 Credits of Elective Course Even
Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this courses, students are able to:

CO 1. Understand and explain advanced seismic imaging methodologies.
CO 2. Carry out advanced seismic data processing and analyze the results.

SYLLABUS

Rock physics for seismic modelling, Rock properties and Amplitude versus offset (AVO) analysis, Seismic trace inversion, AVO Inversion, Methodology, Full Waveform Inversion (FWI), initial modeling (travel-time tomography, reflection tomography, stereotomography), numerical methods of seismic wave modeling (finite difference, finite element, discontinuous galerkin finite element, spectral element), selection of objective functions/misfits, gradient calculations using the adjoint method, techniques numerical optimization for FWI.

REFERENCES

1. Simm, R. and Bacon, M. (2014), Seismic Amplitude: An Interpreter's Handbook, Cambridge University Press.
2. Wang, Y., (2003), seismic amplitude inversion in reflection tomography, Pergamon, Elsevier science ltd.
3. Avseth, P., Mukerji, T., and Mavko, G. (2005), Quantitative seismic Interpretation , Cambridge University Press.
4. Virieux, J., Asnaashari, A., Brossier, R., Métivier, L., Ribodetti, A., & Zhou, W. (2017). An introduction to full waveform inversion. In Encyclopedia of exploration geophysics (pp. R1-1). Society of Exploration Geophysicists.
5. Fichtner, A. (2010). Full seismic waveform modelling and inversion. Springer Science & Business Media.

MFF 5070 DATA SCIENCE FOR GEOSCIENCES

MFF 5070 *Data Science for Geosciences*
(2 Credits of Elective Course Even
Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this courses, students are able to:

CO 1. Understand and practice the visual and statistical data review process on geoscientific data.
CO 2. Understand and practice the feature engineering process on geoscientific data.
CO 3. Understand and practice machine learning algorithms for geoscientific data.

SYLLABUS

Review and prospects of data science in geoscience, standard methodology of data science, the concept of visual and statistical data review, data cleaning and transformation, feature/feature engineering (selection techniques and/or reduction of features qualitatively and quantitatively), classification models (logistic regression, decision tree, naïve Bayer classifier, k-nearest neighbor, boosting algorithm, support vector classifier), regression model (simple linear regression and multi variables, polynomial and non-linear regression, support vector regression, random forest regression), model clustering (distance method, K-means, hierarchical, DBSCAN), Artificial Neural Network (ANN) model and deep learning, model evaluation.

REFERENCES

1. Aggarwal, C. C. (2021). An Introduction to Artificial Intelligence. In Artificial Intelligence (pp. 1-34). Springer, Cham.
2. Bishop, C.M. (2006). Pattern recognition. Machine learning, 128(9).
3. Duda, R.O., & Hart, P. E. (2006). Pattern classification. John Wiley & Sons.

4. Aggarwal, C. C. (2021). An Introduction to Artificial Intelligence. In Artificial Intelligence (pp. 1-34). Springer, Cham.
5. Zheng, A., & Casari, A. (2018). Feature engineering for machine learning: principles and techniques for data scientist."O'Reilly Media, Inc.".

MFF 5915 FRONTIER IN GEOSCIENCES

MFF 5915 *Frontier in Geosciences*
(2 Credits of Elective Course Odd
Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this courses, students are able to:

- CO 1. Know and explain the latest technologies in the field of geophysical methodology.
- CO 2. Know and explain the latest technologies in the field of GIS.
- CO 3. Know and re-explain the latest technology in the field of geophysical electronics and instrumentation.
- CO 4. Know and re-explain the latest technology in the field of geophysical computing.

SYLLABUS

Discussion of the latest research and methodology developments in the field of earth science or geoscience, which includes geophysical data acquisition and processing techniques (seismic, gravitational, magnetic, electromagnetic, and geoelectric), geophysical instrumentation (sensors, data loggers, data processing hardware, and monitoring systems), utilization of geographic information systems (GIS) and photogrammetry.

REFERENCES

1. Jurnal internasional yang relevan dan terbit pada lima tahun terakhir.
2. Buku teks terbaru dari SEG (Society Exploration of Geophysicist).
3. Advances in geophysics (5 volume terakhir).

MFF 5913 GEOTECHNICAL ENGINEERING

MFF 5913 *Geotechnical Engineering*
(2 Credits of Elective Course Odd
Semester)

PREREQUISITE

None

LEARNING OBJECTIVES

After taking this courses, students are able to:

- CO 1. Understanding the physical properties of soil/rock near the surface related to geotechnical matters.
- CO 2. Understand the application of physics/geophysics in geotechnical analysis.
- CO 3. Understand the geophysical acquisition, processing and interpretation of landslide geotechnical cases.

CO 4. Understand the geophysical acquisition, processing and interpretation of liquefaction geotechnical cases.

SYLLABUS

Introduction to Geotechnical Engineering, grain size analysis, weight-volume relationship, plasticity, soil classification and soil compaction, Study of stress in soil mass, Consolidation and shear strength of soils, Subsurface exploration, and Cases of geotechnical engineering studies (example: slope stability, retaining walls, foundations, and liquefaction).

REFERENCES

1. Das, B.M. and Sivakugan, N., 2016. Introduction to Geotechnical Engineering, 2nd ed., Cengage Learning, Boston. USA. ISBN: 978-1-305-25732-0.
2. Sutharam, T.G., Jakka, R., and Kolathayar, S., 2021. Latest Developments in Geotechnical Earthquake Engineering and Soil Dynamics. Springer Transaction in Civil and Environmental Engineering, Singapore. https://doi.org/10.1007/978- 981-16-1468-2

ELECTIVE COURSES
RESEARCH PATH (*BY RESEARCH*)

MFF 6011 RESEARCH I

MFF 6011 *Research I*

(3 Odd Semester MKP Credits - Even)

PREREQUISITE

Can only be taken by students on the research path

LEARNING OBJECTIVES

After taking this courses, students are able to:

- CO 1. Prepare a research proposal consisting of background, problem formulation, problem boundaries and research objectives.
- CO 2. Compile a literature review from literature searches related to the research to be carried out.
- CO 3. Develop and master the theoretical basis that underlies the research study to be committed.
- CO 4. Determine research methods and design research plans and schedules.

SYLLABUS

Students submit their research proposals in a seminar at the end of the semester. The research proposal contains about: Research background that leads to the formulation of the problem, the limitations of the problem and the objectives of the research; Literature review in the form of results those previous researchers have obtained; The theoretical basis underlying the research study to be carried out; Research methods; Research plans and schedules.

REFERENCES

Buku Panduan dan Template Penulisan Tugas Akhir.

MFF 6012 RESEARCH I

MFF 6012 *Research II*

(3 Odd Semester MKP Credits - Even)

PREREQUISITE

Can only be taken by students on the research path

LEARNING OBJECTIVES

After taking this courses, students are able to:

CO 1. Make a hypothesis based on the data or the initial results of the research.

CO 2. Identify problems and obstacles that can arise in the research.

CO 3. Make a logbook of research activities.

SYLLABUS

Students convey the development of their research in the form of preliminary results and verification of initial hypotheses. It also conveyed the various obstacles faced and their solutions. Students are required to submit a logbook of their research before the seminar.

MFF 6013 RESEARCH III

MFF 6013 *Research III*

(3 Odd Semester MKP Credits - Even)

PREREQUISITE

Can only be taken by students on the research path

LEARNING OBJECTIVES

After taking this courses, students are able to:

CO 1. Conduct analysis, discussion and discussion of the data or the final results of the research.

CO 2. Summarizing the results of the research.

SYLLABUS

Delivering paper presentations in a national seminar. The national seminar that is attended must be with the permission of the academic supervisor/thesis. Before the presentation at the national seminar, a limited presentation was made within the scope of KBK, guided by an academic supervisor/thesis.

MFF 6021 NATIONAL SEMINAR

MFF 6021 *National Seminar*

(3 Odd Semester MKP Credits - Even)

PREREQUISITE

Can only be taken by students on the research path

LEARNING OBJECTIVES

After taking this courses, students are able to:

CO 1. Explaining research and research results in a concise form of presentation in Bahasa.
CO 2. Presenting research and research results in an international seminar in Bahasa.

SYLLABUS
Delivering paper presentations in a national seminar. The national seminar that is attended must be with the permission of the academic supervisor/thesis. Before the presentation at the national seminar, a limited presentation was made within the scope of KBK, guided by an academic supervisor/thesis.

MFF 6022 INTERNATIONAL SEMINAR
MFF 6022 *International Seminar*
(4 Odd Semester MKP Credits - Even)
PREREQUISITE
Can only be taken by students on the research path

LEARNING OBJECTIVES
After taking this courses, students are able to:
CO 1. Explaining research and research results in a concise form of presentation in a foreign language (especially in English).
CO 2. Presenting research and research results in an international seminar in a foreign language (especially in English).

SYLLABUS
Delivering paper presentations in an international seminar. International seminars that are attended must be with the permission of the academic supervisor/thesis. Before the presentation at the international seminar, a limited presentation was made within the scope of KBK, guided by academic supervisors/theses.

MFF 6031 SCIENTIFIC PUBLICATIONS A
MFF 6031 Scientific Publication A
(4 Odd Semester MKP Credits - Even)
PREREQUISITE
Can only be taken by students on the research path

LEARNING OBJECTIVES
After taking this courses, students are able to:
CO 1. Prepare a draft publication of the results of his research according to the template of the intended international reputable journal.

SYLLABUS
Students compile a draft manuscript based on the research results conducted during the Master of Research-Based Physics program. The publication manuscript can be either part or part of a Master of Physics thesis research. The draft manuscript of the publication must follow the template of the intended journal. All prerequisites of the intended journal must be met.

MFF 6032 PUBLIKASI ILMIAH B

MFF 6032 *Scientific Publication B*

(5 Odd Semester MKP Credits - Even)

PREREQUISITE

Can only be taken by students on the research path.

LEARNING OBJECTIVES

After taking this courses, students are able to:

- CO 1. Conduct correspondence and answer objections from editors and reviewers of reputable international journals.
- CO 2. Correct and change to the draft publication according to the request of editors and reviewers of the intended international reputable journal.

SYLLABUS

Students conduct correspondence and improvements to the draft publication manuscript by input and criticism from journal reviewers. If necessary, changes to the intended journal can be made with the permission of the academic supervisor/thesis. Publication manuscripts must be declared to have been accepted to be published in the intended reputable international journal.