HIGHER EDUCATION CURRICULUM DOCUMENT

STUDY PROGRAM

UNDERGRADUATE PROGRAM IN PHYSICS
FACULTY OF MATHEMATICS AND NATURAL SCIENCES
UNIVERSITY OF INDONESIA
2020

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CHAPTER 1 INTRODUCTION

The learning systems of formal education in general and Higher Education in particular are required to change drastically in the era of disruption and industrial revolution 4.0 (RI 4.0) where the products of learning outcomes have to be ready in facing the sudden changes of time. The products of learning are required to have skills, knowledge, and Outcomes (competency) which cannot be replaced by machines or artificial intelligence. So in the learning systems, the outcomes of learners become the main focus in the formulation of the curriculum (outcome-based learning). This is in line with the demands of global Education quality as stated in the international accreditation. The old curriculum is considered no longer relevant to be applied in the current era which demands flexibility and an open source learning concept. Online learning resources are available from various universities around the world that are accessible to students. The old curriculum still adopts centralized learning in only one study program or university. Meanwhile, the open source learning concept requires the widest possible space for learners to access learning materials from another study program or university and from experts in their fields both at home and abroad. Therefore, a curriculum design that provides strong concept understanding of one study program and the opportunity to deepen the concept in another study program or university or even apply it directly in the community is needed.

The Regulation of the Minister of Education and Culture of the Republic of Indonesia Number 03/2020 is the basic reference in changing the university curriculum towards the independent campus concept. By definition, curriculum is a set of plans and arrangements regarding the objectives, contents, and materials of learning and the methods used as guidelines for implementing learning activities to achieve higher Education goals. Curriculum designed by university must facilitate learning in the following ways:

- The learning in the study program consists of at least 4 semesters and a maximum of 11 semesters.
- The learning outside the study program in the same university consists of 1 semester or 20 credits.
- A maximum of 2 semesters or the equivalent of 40 credits are:
  - The learning in the same study program at a different university,
  - The learning at a different study program at a different university,
  - The learning outside the university.

The minimum number of credits that must be taken in the Bachelor Degree Education is still 144 credits and within a maximum of 7 academic years. A one-credit course learning consists of 50 minutes per week per semester of learning process activities, 60 minutes per week per semester of structured assignment activities and 60 minutes per week per semester of independent activities. As for laboratory work, 1 credit is equivalent to 170 minutes of laboratory work activities per week per semester.

The construction of the curriculum of the Undergraduate Program in Physics 2020 (Curriculum 2020) is aligned with the regulations of the National Standards of Higher Education (SN DIKTI) which are contained in the Regulation of the Minister of Research, Technology, and Higher Education of the Republic of Indonesia Number 44/2015 and the Indonesian National Qualification Framework (KKNI) which is contained in Presidential Decree Number 08/2012 for the bachelor degree level. Curriculum 2020 is flexible with continuous improvement based on the output evaluation results of learning activities in a comprehensive manner by applying a cycle of plan, do, check, and act.

The Curriculum 2020 composition consists of 100 credits of the compulsory courses of the Undergraduate Program in Physics and 44 credits of independent learning. Independent learning allows students to choose one of the following schemes:

Full one study program. Taking all Physics and Applied Physics courses in the Undergraduate Program in Physics.

Major-minor. Taking a major in the Undergraduate Program in Physics and a minor in a study program outside the Undergraduate Program in Physics.

Double majors. Taking a major in the Undergraduate Program in Physics and a second major in another study program and obtaining 2 bachelor degrees.

Free choice. Carrying out learning activities outside the Undergraduate Program in Physics or the University such as KKN (community service program), student exchange, research internship, project/independent study, humanism/social activity, teaching, internship, and art and sport activities. The Regulation of the Minister of Education and Culture of the Republic of Indonesia Number 03/2020 article 18 has stipulated that the 1-credit learning process is counted as 170 minutes per week per semester.

Undergraduate-to-Master or Undergraduate-to-Doctor fast track programs. With a 3.25 minimum GPA requirement, students can continue their studies to pursue a master's to doctoral degrees starting from the 6th semester at the bachelor level.

Curriculum 2020 started in the early 2020 academic year. The independent campus learning system has given students the opportunity to choose the learning scheme as desired and build skills according to the intended profession. The learning system will use the blended learning method which allows students to access online lectures. Courses can be taken from the university itself or outside the study program, the university, or abroad.

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CHAPTER 2 GRADUATE PROFILE OF THE UNDERGRADUATE PROGRAM IN PHYSICS

2.1 Vision of the Undergraduate Program in Physics

To become a center for education and research in the field of Physics and Applied Physics that is superior and competitive and able to solve problems and challenges at the national and global levels, towards excellence in Southeast Asia.

2.2 Missions of the Undergraduate Program in Physics

1. To maintain and strengthen the excellence in education and research in the fields of Physics and Applied Physics.
2. To improve the internal management that is able to encourage the active and productive involvement of teaching staff/lecturers and students to increase scientific activities and scientific works in the field of Physics and Applied Physics with national and international qualities.
3. To actively participate in providing services as a manifestation of the dedication and contribution of Physics and Applied Physics to community.
4. To prepare graduates who are ready to compete in the global market.

2.3 Graduate profile

Bachelor of Science in Physics who is able to think critically and creatively with a strong understanding of physics to build a professional career and to continue their education to a higher level, in the field of Physics or a related field.

2.4 List of Program Learning Outcomes (PLOs)

<u>Main Program Learning Outcomes</u>

1. Applying classical and modern Physics concepts in general physics problems.
2. Applying mathematical methods to solve Physics problems analytically and computationally.
3. Applying the concepts of one of the following fields of Physics or Applied Physics:
    a. Theoretical Nuclear & Particle Physics
    b. Materials Physics
    c. Condensed Matter Physics
    d. Instrumentation Physics
    e. Medical Physics & Biophysics
4. Formulating problems and solving Physics and its application, as well as interdisciplinary problems related to science and mathematics clusters critically, creatively, and innovatively.

5. Explaining the basic principles of experiments, applying the measurement methods of Physics, and able to analyze the results correctly.
6. Summarizing the basic knowledge in science and technology.
7. Applying the knowledge of Physics in community and practical life, as well as identifying and adapting to new things.
8. Developing and deepening the knowledge gained in the bachelor degree program in a sustainable manner, and being able to continue to the master's and doctoral education levels.
9. Practicing attitudes and skills that support success at work and in participating in community activities.
10. Having the knowledge of the basic elements of Bahasa Indonesia and English of the field of Physics in particular and science and technology in general.
11. Solving simple scientific problems and presenting them orally and in writing.

Supporting Program Learning Outcomes

1.1 Formulating the problems in and solutions to mechanics physics, electrodynamics, thermodynamics, vibrations, waves, optics, electricity and magnetism.
1.2 Explaining the concepts of quantum physics, atoms and molecules, core, elementary particles, and solid physics.
2.1 Deriving formulas specific to the problem at hand.
2.2 Performing analytical and numerical calculations.
5.1 Describing the working principles of electronic components.
5.2 Measuring physical quantities.
5.3 Processing data.
5.4 Interpreting data.
6.1 Describing contemporary & cutting-edge phenomena, findings, and science and technology topics.
6.2 Building insight into the latest developments in science and technology related to physics.
7.1 Applying the basic concepts of physics.
7.2 Implementing scientific ethics in the community.
7.3 Adapting well to the social life.
7.4 Being able to operate and utilize information and communication technology.
7.5 Learning the latest instruments that support their work.
7.6 Applying physics in the production process.
8.1 Having the knowledge of lifelong learning strategy
9.1 Implementing scientific rules.
9.2 Implementing good time management.
9.3 Implementing effective learning and working methods.
9.4 Being able to work in a team.

9.5 Carrying out standard operating procedures.

9.6 Creating complete work plans.

10.1 Being able to use spoken and written language well in Bahasa Indonesia and English for academic and non-academic activities.

11.1 Being able to communicate the results of scientific works.

11.2 Being able to compose research reports.

11.3 Being able to write scientific articles.

2.5 Learning Outcome Network

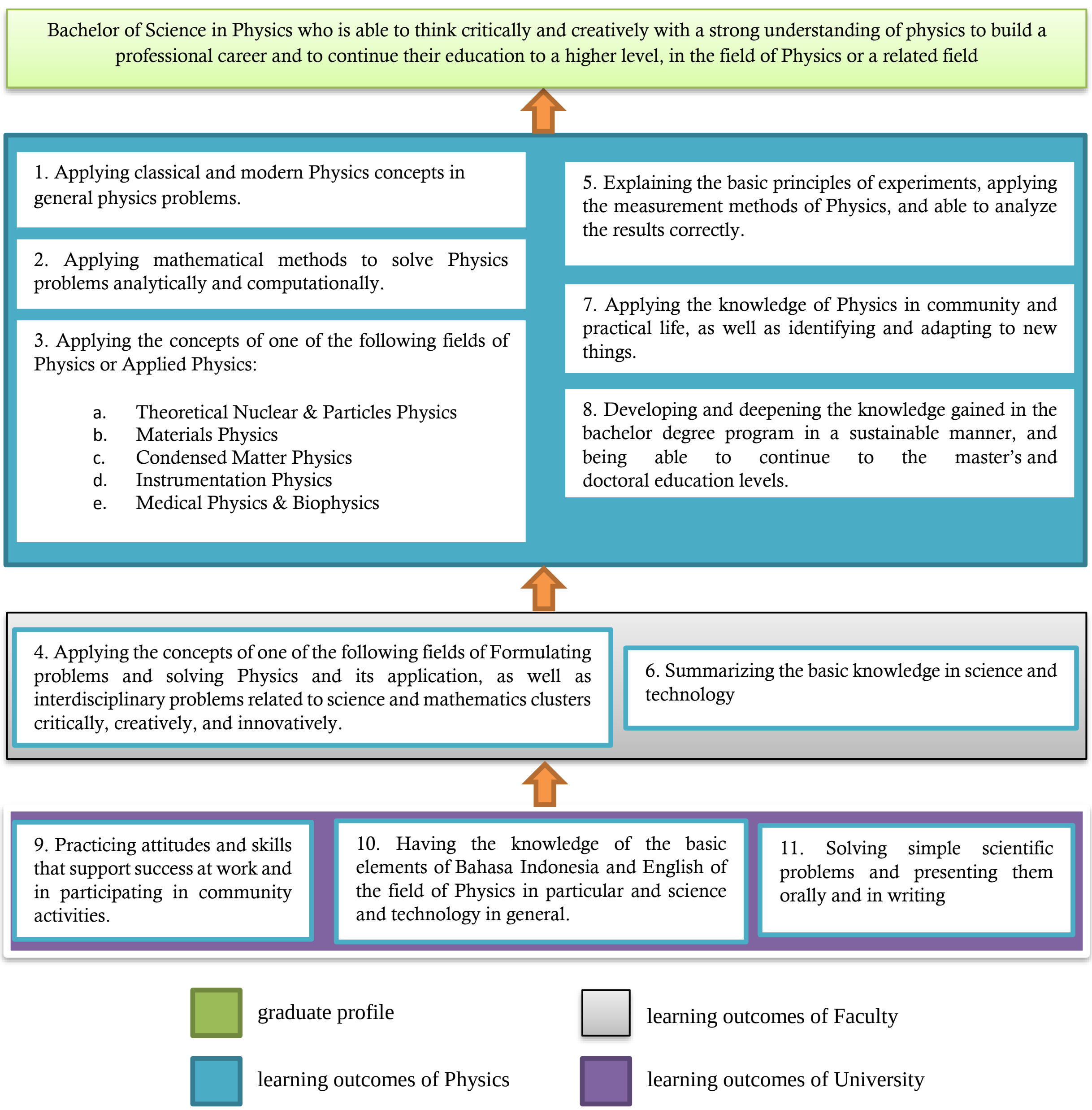

Figure 1. Main Program Learning Outcome Network

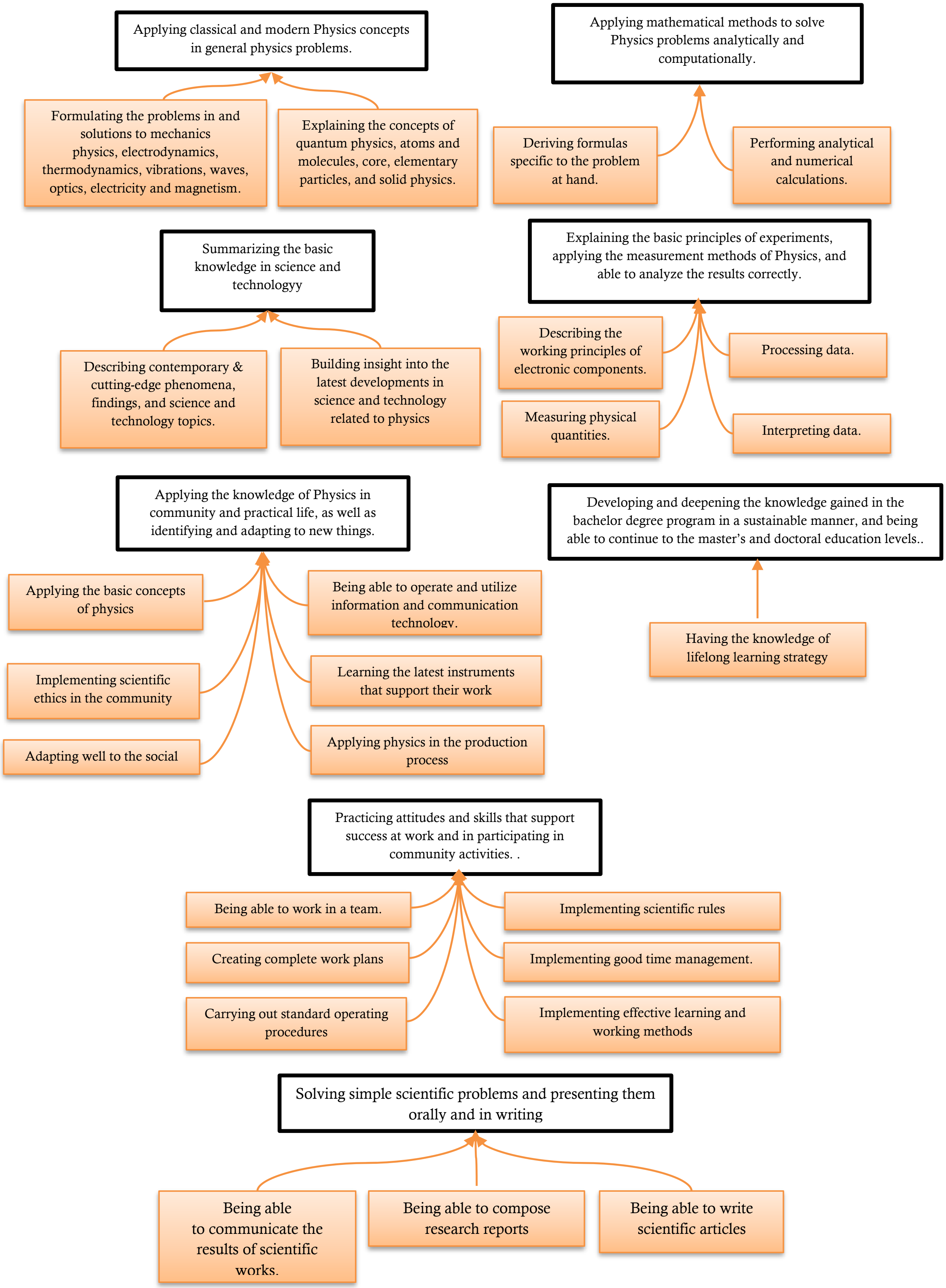

Figure 2. Supporting Program Learning Outcome Network

CHAPTER 3 GRADUATE LEARNING OUTCOMES OF THE STUDY PROGRAM

3.1 Matrix 0/Equivalent to KKNI

Table 3.1. Matrix 0 Equivalent to KKNI

Sentence Number of KKNI	KKNI Descriptor of Level 6	Program Leaning Outcomes	Requirement
1	Being able to apply their field of expertise and take advantage of science and technology in their field in solving problems and able to adapt to situation at hand.	3. Applying the concepts of one of the following fields of physics: a. Theoretical Nuclear & Particle Physics b. Materials Physics c. Condensed Matter Physics d. Instrumentation Physics e. Medical Physics & Biophysics	practical work report, field assignment report, thesis, discussion form, presentation form, scientific paper
		4. Formulating the problems in and solutions to physics and its application, as well as interdisciplinary problems related to the science and mathematics cluster critically, creatively, and innovatively.	
		5. Explaining the basic principles of experiments, applying the measurement methods of physics, and being able to analyze the results correctly.	
		6. Summarizing basic knowledge in the field of science and technology.	
		7. Applying knowledge of physics in community and practical life, as well as identifying and adapting to new things.	

		8. Developing and deepening the knowledge gained in the bachelor degree program in a sustainable manner, and being able to continue to the master's degree level.	
2	Mastering the theoretical concepts of a particular field of knowledge in general and the theoretical concepts of a special section in that field of knowledge in depth, and being able to formulate the solutions to procedural problems	1. Applying classical and modern physics concepts in solving general physics problems.	laboratory work report, course assignment report and exam, thesis, scientific paper
		2. Applying mathematical methods to solve physics problems analytically and computationally.	
3	Being able to make correct decisions based on analysis of information and data, and able to provide guidance in choosing various alternative solutions independently and in groups	10. Having the knowledge of the basic elements of Bahasa Indonesia and English of physics in particular and science in general.	practical work report, field assignment report, thesis, presentation in seminar, scientific paper
		11. Solving simple scientific problems and presenting them orally and in writing.	
4	Being responsible for their own work and can be given responsibility for the achievement of the work of the organization.	9. Practicing attitudes and skills that support the success at work and in participating in community activities	practical work report, field assignment report, thesis, scientific paper

3.2 .Matrix 0A/EQUIVALENT TO SN DIKTI

A. ATTITUDE FORMULATION

Every graduate of the bachelor degree program must have the following attitudes:

a. devoted to God Almighty and able to show a religious attitude;

b. upholding human values in carrying out duties based on religion, morals and ethics;

c. contributing to improving the quality of life in community, nation, state, and advancement of civilization based on Pancasila;

d. playing a role as a citizen who is proud and loves the country, has nationalism and a sense of responsibility to the state and nation;

e. respecting the diversity of cultures, views, religions and beliefs, as well as the original opinions or findings of others;

f. cooperating and having social sensitivity and care for the community and the environment;

g. obeying the law and discipline in social and state life;

h. internalizing academic values, norms, and ethics;

i. showing an attitude of responsibility for the work in their field of expertise independently; and

j. internalizing the spirit of independence, struggle, and entrepreneurship.

C. General Skill Formulation:

Table 3.2 General Skill Formation

No	Bachelor Skills (SN DIKTI)	General Skills of Bachelor of Physics Level
a	Being able to apply logical, critical, systematic, and innovative thinking in the context of developing or implementing science and technology that pays attention to and applies humanities values in accordance with their field of expertise;	Demonstrating integrity and critical, creative, and innovative thinking and having the intellectual curiosity to solve problems at the individual and group levels.
b	Being able to demonstrate independent, quality and measurable performance;	Handling general and specific problems in the field of physics. Carrying out measurements, processing, and analysis of physical quantities Designing programming algorithms and model simulations in physics.
c	Being able to study the implication of the development or implementation of technological science that pays attention to and applies humanities values according to their expertise based on scientific rules, procedures and ethics in order to produce solutions, ideas, designs or art criticism, to compile scientific descriptions of the results of their study in the form of a thesis or final	Formulating comprehensive solutions in solving physics problems with the help of science, technology, and art.

	assignment report, and to upload it on the university page;	
d	Compiling a scientific description of the results of the above study in the form of a thesis or final assignment report, and uploading it on the university page;	Compiling scientific writings on research results in the form of thesis and scientific paper
e	Being able to make decisions appropriately in the context of problem solving in their area of expertise, based on the results of information and data analysis;	Recommending alternative solutions to problems in the community, nation, and state. Formulating problems in the field of physics and providing alternative solutions based on the results of information and data analysis.
f	Being able to maintain and develop networks with mentors, colleagues, and peers both inside and outside the institution;	Identifying various entrepreneurial opportunities in one field of physics. Utilizing the network owned by mentors and colleagues both inside and outside the institution.
g	Being able to be responsible for the achievement of group work and to supervise and evaluate the completion of work assigned to workers who are under their responsibility;	Demonstrating a leadership attitude in supervising and assessing the tasks performed by the work group under their responsibility.
h	Being able to carry out the self-evaluation process of the work group under their responsibility, and able to manage learning independently; and	Self-evaluating the tasks carried out by the work group under their responsibility, and being able to make the results of the evaluation as learning.
i	Being able to document, store, secure, and recover data to ensure validity and prevent plagiarism.	Managing data documentation properly

3.3 .MATRIX I COURSES AND LEVELS OF OUTCOMES

Table 3.3. Matrix I Courses and Levels of Outcomes

Level / Cluster	Main Outcomes	Supporting Outcomes	Other Outcomes
Basic and Personality		Practicing attitudes and skills that support success at work and in participating in community activities.	
		Applying the concepts of one of the following fields of physics:	

		a. Theoretical Nuclear and Particle Physics b. Materials Physics c. Condensed Matter Physics d. Instrumentation Physics e. Medical Physics & Biophysics Developing and deepening the knowledge gained in the bachelor degree program in a sustainable manner, and be able to continue to the master's and doctoral degree levels.	
Work Behavior		Applying the concepts of one of the following fields of physics: a. Theoretical Nuclear and Particle Physics b. Materials Physics c. Condensed Matter Physics d. Instrumentation Physics e. Medical Physics & Biophysics	
		Having the knowledge of the basic elements of Bahasa Indonesia and English of the field of Physics in particular and science and technology in general	Being able to use spoken and written language well in Bahasa Indonesia and English for academic and non-academic activities
Field of Knowledge	Applying classical and modern physics concepts in general physics problems	Being able to communicate the results of scientific works	Implementing effective learning and working methods.
	Formulating problems and solutions to mechanics physics, electricity and magnetism, optics, thermodynamics, and modern physics	Being able to compose research reports	
	Explaining the concepts of quantum physics, atoms and molecules, nuclei, elementary particles, and solid physics.	Being able to write scientific articles	
	Applying mathematical methods to solve physics problems analytically and computationally.	Summarizing the basic knowledge in science and technology.	
	Formulating problems and solving Physics and its application, as well	Building insights into the latest developments in science and technology related to physics	

	as interdisciplinary problems related to science and mathematics clusters critically, creatively, and innovatively		
	Explaining the basic principles of experiments, applying the measurement methods of Physics, and being able to analyze the results correctly.	Describing contemporary & cutting-edge phenomena, findings, physics topics.	
	Solving simple scientific problems and presenting orally and in writing	Applying the concepts of one of the following fields of physics:	
	Deriving formulas specific to the problem at hand	a. Theoretical Nuclear and Particle Physics	
	Performing analytical and numerical calculations.	b. Materials Physics	
	Describing the working principles of electronic components	c. Condensed Matter Physics	
	Measuring physical quantities	d. Instrumentation Physics	
	Processing data	e. Medical Physics & Biophysics	
	Interpreting data		
	Applying the basic concepts of physics.		
Occupational Skills	Applying the basic concepts of physics in the community and practical life.	Learning the latest instruments that support their work	Being able to operate and utilize communication and information technology
	Solving simple scientific problems and presenting them orally and in writing.	Practicing attitudes and skills that support success at work and in participating in community activities.	Implementing good time management.
		Being able to work in a team	Applying physics in the production process
		Creating complete work plans	
		Carrying out standard operating procedures	
		Learning and adapting to new things.	
		Applying the concepts of one of the following fields of physics:	
		a. Theoretical Nuclear and Particle Physics	
		b. Materials Physics	
		c. Condensed Matter Physics	

		d. Instrumentation Physics e. Medical Physics & Biophysics	
Social Life	Applying the basic concepts of physics in the community and practical life, as well as identifying and adapting to new things.	Practicing attitudes and skills that support the success at work and in participating in community activities.	Having the knowledge of lifelong learning strategy
		Implementing scientific ethics in the community	
		Adapting well to the social life	
		Applying the concepts of one of the following fields of physics: a. Theoretical Nuclear and Particle Physics b. Materials Physics c. Condensed Matter Physics d. Instrumentation Physics e. Medical Physics & Biophysics	

3.4 Matrices II and II Learning Experience

Table 3.4. Matrices II and II Learning Experience

Outcome	Learning Experience		Study Material (Scope of Material)	Media and Technology	Course	Indicator	Assessment
	Sub outcome	*Method activity*	*Substance: topic and subtopic*				
1. Applying classical and modern physics concepts in solving general physics problems.	Formulating problems in and solutions to mechanics physics, electricity and magnetism, optics, thermodynamics, and modern physics.	Face-to-face lecture , online learning, group discussion and presentation, independent assignment, laboratory work	Classical Mechanics, Vibrations & Waves, Electricity & Magnetism, Optics, Thermodynamics	board, lcd, laboratory, internet, online media	Basic Physics 1&2, Basic Physics Laboratory Work 1 & 2	Explain the concepts in Classical Mechanics, Vibrations & Waves, Electricity & Magnetism, Optics, Thermodynamics	exam, assignment, presentation and discussion, laboratory work report
			Advanced Classical Mechanics, Advanced Vibrations & Waves, EM Waves, EM Field, Advanced Thermodynamics, Modern Physics,		Modern Physics, Thermodynamics, Classical Mechanics, Vibrations & Waves, Electromagnetic Field 1&2, Advanced Physics	Explain the concepts in Advanced Classical Mechanics, Advanced Vibrations & Waves, EM Waves, EM Field, Advanced Thermodynam	

			Special Relativity		Laboratory Work 1&2	ics, and Modern Physics.	
	Explaining the concepts of quantum physics, atoms and molecules, nuclei, elementary particles, and solid physics		Statistical Physics, Quantum Physics, Solid-state Physics, Nuclear Physics	board, lcd, computer, laboratory, internet, online media	Quantum Physics 1&2, Statistical Physics, Nuclear Physics, Solid-state Physics	Explain the concepts in Statistical Physics, Quantum Physics, Solid-state Physics, Nuclear Physics	
2. Applying mathematical methods to solve physics problems analytically and computationally	Deriving formulas specific to the problem at hand	Face-to-face lecture , online learning, discussion and presentation, independent assignment	Classical Mechanics, Vibrations & Waves, Electricity & Magnetism, Optics, Thermodynamics, Mathematics	board, lcd, computer, laboratory, internet, online media	Basic Physics 1&2, Calculus 1 & 2, Elementary Linear Algebra	1. Determining the equation that becomes the starting point for solving calculation 2. Generating the final equation to calculate the desired physical quantity	exam, assignment, presentation and discussion
	Performing analytical and numerical calculations.	Face-to-face lecture , online learning, independent assignment	Calculus, Linear Algebra and Differential Equations, Vector Analysis,		Calculus 1&2, Elementary Linear Algebra, Mathematical Methods in Physics 1-3	Completing analytical calculations to produce a physical quantity	exam, assignment, presentation and discussion

			Complex Analysis			value and/or function or equation for physical quantity	
		Face-to-face lecture , online learning, independent assignment, practice using software in the computer laboratory	Numerical methods for root functions, fitting, interpolation, integration, differentiation, etc., computer programming, use of computational assistive software		Computational Physics	1. Converting analytical equations into numerical equations 2. Determining the appropriate numerical method for the problem at hand 3. Writing computer programs for numerical calculations	
3. Applying the concepts of one of the following fields of physics: a. Theoretical Nuclear and Particle Physics b.Materials Physics c.Condensed Matter Physics		Face-to-face lecture, online learning, independent assignment, practice using software in the computer laboratory, research/industrial internship,	Contents related to the development of physics in the field of: a. Theoretical Nuclear and Particle Physics b.Materials Physics	board, lcd, computer, laboratory, internet, online media	Elective Courses, Free learning.	Using the basic concepts of physics courses to conduct deeper development into one of the fields: Contents related to the	

d. Instrumentation Physics e.Medical Physics & Biophysics		other free learning.	c.Condensed Matter Physics d. Instrumentation Physics e.Medical Physics & Biophysics			development of physics in the field of: a. Theoretical Nuclear and Particle Physics b.Materials Physics c.Condensed Matter Physics d. Instrumentation Physics e.Medical Physics & Biophysics	
4. Formulating problems and solving Physics and its application, as well as interdisciplinary problems related to science and mathematics clusters critically, creatively, and innovatively.		Conducting scientific literature tracing, reading scientific articles, learning the basic concepts of physics, solving conceptual as well as calculation problems, making thesis to be presented and discussed in groups	Vibrations & Waves, Electricity & Magnetism, EM Waves & Optics, Medan E. M, Thermodynamics, Statistical Physics, Modern Physics, Quantum Physics, Solid-state Physics, Nuclear Physics,	board, lcd, computer, laboratory, internet, online media	All Physics core courses, all laboratory works, Elective Courses, Free learning.	Explain the concepts in Classical Mechanics, Vibrations & Waves, Electricity & Magnetism, EM Waves & Optics, EM Field, Thermodynamics, Statistical Physics, Modern Physics, Quantum Physics, Solid-	exam, assignment, presentation and discussion

						state Physics, Nuclear Physics,	
5. Explaining the basic principles of experiments, applying the measurement methods of Physics, and able to analyze the results correctly.	Describing the working principle of electronic components	Learning the basic concepts of electronics, conducting electronics experiments through face-to-face lecture , online learning, discussion and presentation, independent assignment, laboratory work	Diodes, Transistors, Amplifiers, Power Supply, Operational Amplifiers, Electronics Digital and Introduction to Microprocessors	board, lcd, computer, laboratory, internet, online media	Electronics 1&2, Electronics Laboratory Work 1&2	Knowing and differentiating the characteristics of analog, digital, and microprocessor components	exam, assignment, presentation and discussion, laboratory work report
	Measuring physical quantities	Studying laboratory work guidelines, using measuring instrument for physics quantities, conducting measurement, writing measurement results through face-to-face lecture , online learning, discussion and presentation,	Experimental and measurement methods, materials in all laboratory works	board, lcd, computer, laboratory, internet, online media	Measurement Physics, all laboratory works	1. Determining the appropriate measurement method for the quantity to be measured 2. Determining and using the right measuring instrument 3. Stating the measurement results	exam, assignment, presentation and discussion, laboratory work report

		independent assignment, laboratory work					
	Processing data	Research in research laboratory, reading data, displaying data in various forms of graphs, finding data characteristics	the basic of statistics, final assignment material and all laboratory works		Introduction to Data Science, Measurement Physics, Statistical Physics, Physics komputasi, Thesis, all laboratory works	Stating the physical properties of the observed system and / or the behavior of physical quantities that are measured / calculated based on the data obtained / presented	exam, assignment, presentation and discussion, laboratory work report
	Interpreting data	Literature review, research in research laboratory, discussion and presentation	final assignment material and all laboratory works		Thesis, all laboratory works	Stating the physical properties of the observed system and / or the behavior of physical quantities that are measured / calculated based on the data obtained / presented	Laboratory work report, final assignment seminar
6. Summarizing the basic knowledge in science and technology.	Describing contemporary & cutting-edge phenomena,	literature study (textbooks and scientific articles), deriving formulas,	quantum concepts, statistical physics, electromagneti	board, lcd, computer, laboratory, internet, online media	Introduction to Data Science, Biologi umum, General	Explaining topics, contemporary and current physical	exam, assignment, presentation and discussion,

	findings, science and technology topics	experiment in laboratory, presentation	sm, and their application		Chemistry, Seminar, Thesis.	phenomena from the point of view of quantum physics, statistical physics, electromagnetism	laboratory work report, final assignment seminar
	Building insights into the latest developments in science and technology related to physics	Literature study (textbooks and scientific articles), deriving formulas, experiment in laboratory, presentation	quantum concepts, statistical physics, electromagnetism, and their application	board, lcd, computer, laboratory, internet, online media	Modern Physics, Quantum Physics 1 & 2, Statistical Physics, EM Field 1 & 2, Thesis	Explaining topics, contemporary and current physical phenomena from the point of view of quantum physics, statistical physics, electromagnetism	exam, assignment, presentation and discussion, laboratory work report, final assignment seminar
7. Applying the basic concepts of physics in the community and practical life, as well as identifying and adapting to new things.	Applying the basic concepts of physics	Case study, group discussion, presentation	All contents of the core courses of Physics stated in the column above	board, lcd, computer, laboratory, internet, online media	PKPKPT, Seminar, Thesis, Elective Courses, Free learning.	Solving hypothetical problems in the community related to physics, completing a final assignment or thesis in the	exam, assignment, presentation and discussion

						form of a product that integrates science and technology in it	
	Implementing scientific ethics in the community	Case study, group discussion, presentation	Physics, Chemistry, Basic Biology, Social Sciences and Humanities, Religious Education	board, lcd, computer, laboratory, internet, online media	Integrated University Course, Religion, Free learning	Applying ethics in solving hypothetical scientific problems	exam, assignment, presentation and discussion
	Adapting well to the social life	Case study, group discussion, presentation	Physics, Chemistry, Basic Biology, Social Sciences and Humanities, Religious Education	board, lcd, computer, laboratory, internet, online media	PKPKPT, Free learning	Working in groups to solve hypothetical science problems Completing a project from a course and doing good practical work	exam, assignment, presentation and discussion
	Being able to operate and utilize communication and information technology	Using a computer, searching for information via the internet, making presentation materials.	Information and Communicatio n Technology (ICT)	board, lcd, computer, laboratory, internet, online media	Seminar, Thesis, Computational Physics, Free learning	Using ICT in lectures	exam, assignment, presentation and discussion

	Learning the latest instruments that support their work	Literature study (through the internet). Practical work in the institution that uses the related instrument	Basic Physics, Modern Physics, Electronics, Computer, Instrumen mutakhir	board, lcd, computer, laboratory, internet, online media	Basic Physics 1&2, Vibrations & Waves, Modern Physics, Electronics 1 & 2, Computational Physics, Seminar, Thesis, Measurement Physics, and all laboratory works	Describing the cutting-edge instrument that supports their work	exam, assignment, presentation and discussion
	Applying physics in the production process	Free learning, finishing course project	Basic Physics, Modern Physics, Classical Mechanics, Quantum Physics, Statistical Physics, EM Field, Thesis, and Measurement Physics	board, lcd, computer, laboratory, internet	Basic Physics, Modern Physics, Classical Mechanics, Quantum Physics 1 & 2, Statistical Physics, EM Field 1 & 2, Thesis, Practical Work, Measurement Physics	Completing a project from a course and independent learning in industry/lab/community properly	Exam, doing assignment, presenting, and doing practical work.
8. Developing and deepening the knowledge gained in the bachelor degree program in a sustainable	Having the knowledge of lifelong learning strategy	Compilation of the points above this column for Outcome numbers 1-8	Compilation of the points above this column for Outcome numbers 1-8	board, lcd, computer, laboratory, internet, online media	Compilation of the points above this column for Outcome numbers 1-8	Compilation of the points above this column for Outcome numbers 1-8	exam, assignment, presentation and discussion, laboratory

manner, and being able to continue to the master's and doctoral education levels.							work report, final assignment seminar
9. Practicing attitudes and skills that support success at work and in participating in community activities.	Implementing scientific ethics in the community	case study, group discussion, presentation, practicing in contributing thoughts in working on group assignments, studying in groups, carrying out class assignments in groups, Practical Work, following lecture schedule, making reports, making and completing final activity/assignment proposal	Integrated University Course, Religion, English, laboratory work, research	board, lcd, computer, laboratory, internet, online media	PKPKPT, Seminar, Thesis, laboratory works, Free learning	Implementing religious moral values in solving hypothetical problems in community, participating actively in group work, being liked by classmates and having a good personality in interacting with others, managing group discussions well so that goals are achieved	exam, assignment, presentation and discussion, Practical Work
	Implementing good time management.	Case study, group discussion and presentation of problems at individual and group levels	Integrated University Course , Religion	board, lcd, internet, online media	PKPKPT	Thinking critically, creatively and innovatively and having the intellectual curiosity to	exam, assignment, presentation and discussion

						solve problems at the individual and group levels.	
	Implementing effective learning and working methods	Compilation of the points above this column for Outcome numbers 1-8	Compilation of the points above this column for Outcome numbers 1-8	board, lcd, computer, laboratory, internet, online media	Compilation of the points above this column for Outcome numbers 1-8	Compilation of the points above this column for Outcome numbers 1-8	exam, assignment, presentation and discussion, laboratory work report, final assignment seminar
	Being able to work in a team	Studying in groups, carrying out class assignments in groups.	Integrated University Course , Religion, English	board, lcd, computer, laboratory, internet	Laboratory works, PKPKPT, Free learning	Managing group discussions well so that goals are achieved	Exam, assignment, discussion and presentation
	Carrying out standard operating procedures	following lecture schedule, making and completing final activity/assignment proposal	Making Proposal, completing it, making report and presenting by following the determined schedule	board, lcd, computer, laboratory, internet	Thesis (6 credits), Practical Work (2 credits)	The activities are carried out properly and on time and the goals are achieved	Exam, doing assignment, presenting, and doing practical work.
	Creating complete work plans	following lecture schedule, making and completing final	Making Proposal, completing it, making report and presenting	board, lcd, computer, laboratory, internet	Seminar, Thesis	The activities are carried out properly and on time and	Exam, assignment, presentation.

		activity/assignment proposal				the goals are achieved	
10. Having the knowledge of the basic elements of Bahasa Indonesia and English of the field of Physics in particular and science and technology in general.	Being able to use spoken and written language well in Bahasa Indonesia and English for academic and non-academic activities.	Face-to-face lecture , online learning, discussion and presentation, independent assignment, laboratory work in the laboratory	Integrated University Course , English	board, lcd, computer, laboratory, internet, online media	Seminar, Integrated University Course , English	Communicating in spoken and written language well in Bahasa Indonesia and English for academic and non-academic activities.	exam, assignment, presentation and discussion, attendance in seminars
11. Solving simple scientific problems and presenting them orally and in writing	Communicating scientific work results	Literature study tracing, case study, research in laboratory, derivation of analytical or numerical formulas, analysis of research results, discussion and presentation, making proposal and thesis, making scientific work, content similarity evaluation of scientific work.		board, lcd, computer	Seminar, Thesis	Solving problems in physics and applied physics. Present the presentation in a non-lengthy manner and in a clear flow	exam, assignment, presentation and discussion, attendance in seminars
	Making reports research		abstract, report outline, references and list of references, report summary, report format			1. Describing the background, objectives, steps / methods of research / practical work carried out 2. Describe the contents of the	assignment, presentation and discussion, laporan Practical Work, final assignment seminar

						report in a clear flow 3. Presenting clear and logical arguments and interpretation of data 4. Drawing the right conclusions 5. Writing a report / thesis according to the specified format	
	Menulis artikel ilmiah		abstract, article outline, references and list of references, article summary, article format			1. Describing the background, objectives, steps / methods of the research carried out 2. Describing the contents of the article in a clear flow 3. Presenting clear and logical arguments and interpretation of data	assignment, presentation and discussion

						4. Drawing the right conclusions 5. Writing articles in the determined format	

CHAPTER 4 COURSES

4.1 Internal students

The courses in Curriculum 2020 consist of compulsory and elective courses with the following details:

1. Semesters 1 - 5 contain 94 credits of compulsory courses of the Undergraduate Program in Physics and 6 credits of thesis in the 8th Semester, details of which are given in Table 4 .1 for Course Clusters, Table 4.2 for University and Faculty Compulsory Courses and Table 4.3 for course composition per semester.
2. Semesters 6-8 contain free learning with scheme options:
   - **Full one study program**
     44 credits of Elective Courses in the Undergraduate Program in Physics.
   - **Major-minor**
     44 credits of courses in another study program.
   - **Double major**
     95-100 credits of courses in another study program. The number of credits is in accordance with the requirement in the intended study program.
   - **Free choice**
     - KKN
     - Student exchange
     - Research Internship
     - Independent project/study
     - Humanitarian/social activity
     - Teaching
     - Internship
     - Art and sport
   - **Fast track program**
     The number of credits and courses taken is in accordance to the requirements in the intended study program. Fast track program can be taken in the study programs with the same field of science. Within the internal department there are options for the study programs, namely:
     - Master program in Material Science
     - Master program in Physics
     - Doctor program in Materials Science
     - Doctor program in Physics

Students are expected to determine the scheme option by latest in semester 6 after consulting with their Academic Advisor (PA). For the scheme Free Choice accompanied by a mentor, a team of evaluators and the conversion of credits will be carried out by a verification team.

Table 4.1. Course Clusters

Course Type		Credit	Total
Compulsory Courses	University	9	**100**
	Faculty	6	
	Study Program	85	
Elective Courses		44	**44**
Total		144	**144**

Table 4.2. University and Faculty Compulsory Courses

Compulsory Courses	Course Name	Credit
University	Religion	2
	English	2
	Integrated University Course	5
Faculty	General Chemistry	2
	General Biology	2
	Introduction to Data Science	2

Table 4.3 Courses per Semester

No	Semester	Code	Course Name	Credit	Status
Semester 1					
1	1	SCPH601101	Basic Physics 1	4	MKP
2	1	SCPH601142	Basic Physics Laboratory Work 1	1	MKP
3	1	SCMA601120	Elementary Linear Algebra	2	MKP
4	1	SCMA601001	Calculus 1	3	MKP
5	1	SCBI601112	General Biology	2	MKWF
6	1	SCCH601101	General Chemistry	2	MKWF
7	1	SCMF600002	Introduction to Data Science	2	MKWF
8	1	UIGE600004	Religion	2	MKU
9	1	UIGE600003	English	2	MKU
			Total Credits for Semester 1	**20**	
Semester 2					
1	2	SCPH601201	Basic Physics 2	4	MKP
2	2	SCPH601242	Basic Physics Laboratory Work 2	1	MKP
3	2	SCPH601213	Mathematical Methods in Physics 1	3	MKP
4	2	SCPH601254	Electronics 1	2	MKP
5	2	SCPH601245	Electronics Laboratory Work 1	1	MKP
6	2	SCMA601002	Calculus 2	3	MKP
7	2	UIGE600006	Integrated University Course	5	MKU
			Total Credits for Semester 2	**19**	

Semester 3					
1	3	SCPH602111	Mathematical Methods in Physics 2	4	MKP
2	3	SCPH602112	Mathematical Methods in Physics 3	2	MKP
3	3	SCPH602133	Modern Physics	3	MKP
4	3	SCPH602144	Advanced Physics Laboratory Work 1	1	MKP
5	3	SCPH602135	Thermodynamics	3	MKP
6	3	SCPH602156	Electronics 2	2	MKP
7	3	SCPH602147	Electronics Laboratory Work 2	1	MKP
8	3	SCPH602258	Measurement Physics	2	MKP
			Total Credits for Semester 3	**18**	
Semester 4					
1	4	SCPH602221	Electromagnetic Field 1	3	MKP
2	4	SCPH602222	Quantum Physics 1	4	MKP
3	4	SCPH602223	Classical Mechanics	4	MKP
4	4	SCPH602214	Computational Physics	4	MKP
5	4	SCPH602235	Vibrations & Waves	3	MKP
6	4	SCPH602246	Advanced Physics Laboratory Work 2	1	MKP
			Total Credits for Semester 4	**19**	
Semester 5					
1	5	SCPH603121	Electromagnetic Field 2	3	MKP
2	5	SCPH602122	Quantum Physics 2	3	MKP
3	5	SCPH603133	Introduction to Solid State Physics	3	MKP
4	5	SCPH603124	Statistical Physics	4	MKP
5	5	SCPH603135	Introduction to Nuclear Physics	3	MKP
6	5	SCPH603166	Seminar	2	MKP
			Total Credits for Semester 5	**18**	
Semester 6					
			Options		
			1. Full one study program		
			2. Major-Minor		
			3. Double Major		
			4. Free choice		
			5. Fast track		
			Total Credits for Semester 6	**20**	
Semester 7					
			Options		
			1. Full one study program		
			2. Major-Minor		
			3. Double Major		

			4. Free choice		
			5. Fast track		
			Total Credits for Semester 7	**20**	
Semester 8					
1	8	SCPH604261	Thesis	6	
2	8		Electives	4	
			Total Credits for Semester 8	**10**	
			Grand Total	**144**	

Table 4.2 List of Elective Courses

No.	Code	Course Name	Credit	Semester*
1	SCPH603700	Relativistic Quantum Mechanics	4	Even
2	SCPH603701	Classical Field Theory	3	Even
3	SCPH603702	Advanced Computational Physics	3	Even
4	SCPH603703	Introduction to Material Science	4	Even
5	SCPH603704	Applied Materials Physics	3	Even
6	SCPH603705	Material Characterization Methods	4	Even
7	SCPH603706	Transport and Optical Properties of Materials	4	Even
8	SCPH603707	Magnetism	2	Even
9	SCPH603708	Superconductivity	2	Even
10	SCPH603709	Spectroscopy A	2	Even
11	SCPH603710	Sensors and Actuators	2	Even
12	SCPH603711	Sensors and Actuators Laboratory Work	1	Even
13	SCPH603712	Embedded Systems	2	Even
14	SCPH603713	Embedded Systems Laboratory Work	1	Even
16	SCPH603714	Control Systems	2	Even
17	SCPH603715	Control Systems Laboratory Work	1	Even
18	SCPH603716	Introduction to Radiological Physics and Dosimetry	2	Even
19	SCPH603717	Anatomy and Physiology	2	Even
20	SCPH603718	Introduction to Biophysics	2	Even
21	SCPH603719	Health Physics and Radiation Protection	2	Even
22	SCPH604700	Scattering Theory	2	Odd
23	SCPH604701	Nuclear and Particle Physics	3	Odd
24	SCPH604702	Angular Momentum Theory	2	Odd
25	SCPH604703	Capita Selecta of Advanced Material	4	Odd
26	SCPH604704	Spectroscopy B	2	Odd
27	SCPH604705	Methods of Quantum Field Theory for Solids	3	Odd
28	SCPH604706	Nano System Physics	4	Odd
29	SCPH604707	Artificial intelligence	2	Odd

30	SCPH604708	Digital Signal Processing	2	Odd
31	SCPH604709	Data Acquisition System	2	Odd
32	SCPH604710	Instrumentation System	2	Odd
33	SCPH604711	Introduction to Biomaterials	2	Odd
34	SCPH604712	Introduction to Radiotherapy Physics	2	Odd
35	SCPH604713	Introduction to Nuclear Medicine and Medical Imaging Physics	3	Odd
36	SCPH604714	Proyek Riset Laboratory	3	Odd
		Grand Total	**88**	

Note: *available in even/odd semester

INTERCONNECTIVITY OF COURSES

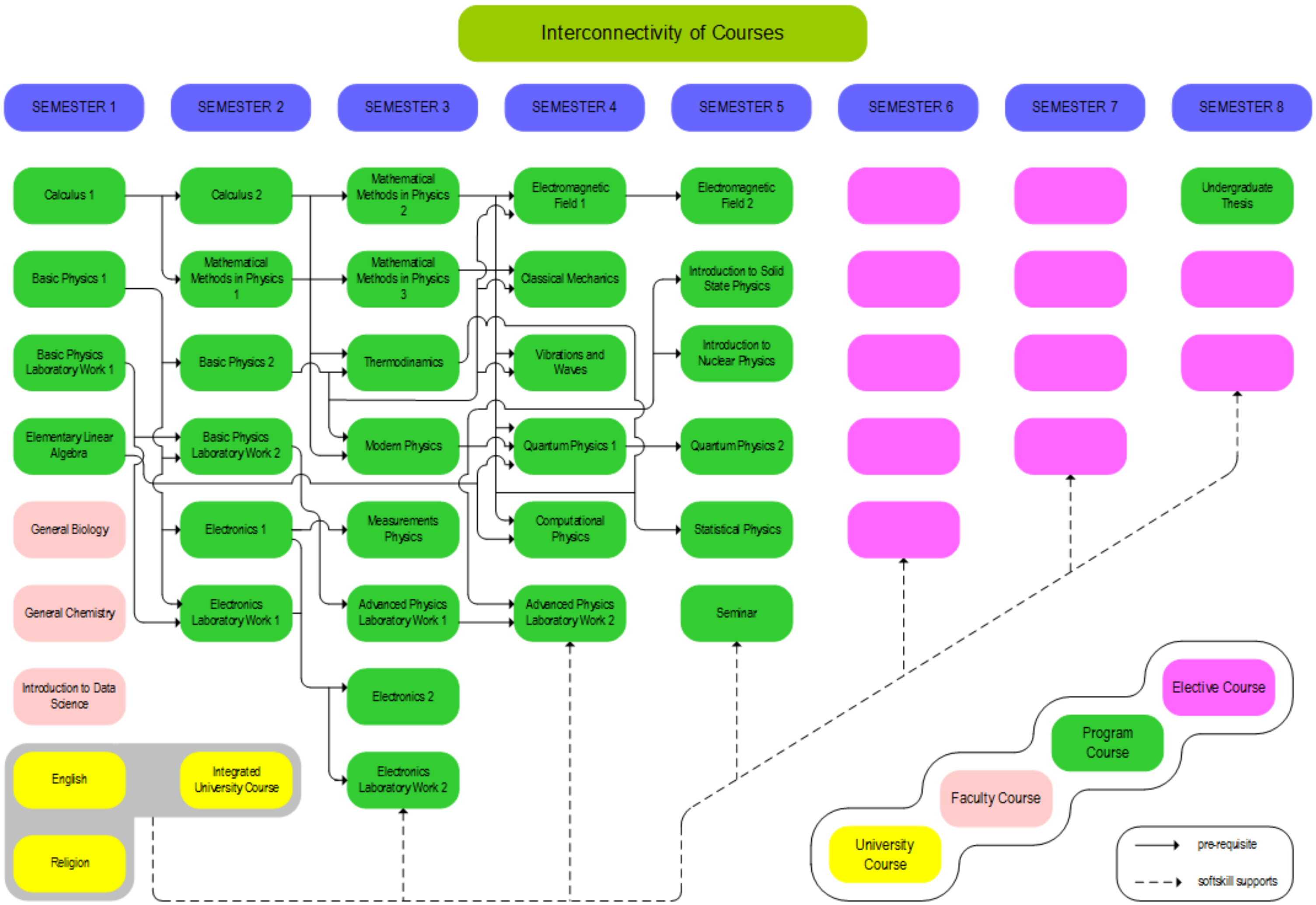

Figure 3. Interconnectivity of Courses

COURSE SYLLABUS

1. **General Biology**

   Code/Credit/Prerequisite: SCBI601112/2 credits/-

   Course Learning Outcome:

   explain the basic concepts of biology in a comprehensive manner and link the basic concepts of biology with other sciences, especially sciences in the same field such as chemistry, physics and mathematics, explain Indonesian biodiversity and its conservation efforts, explain the important role of humans as environmental managers, develop cooperative behavior and teamwork in solving problems especially those related to the environment, develop honest, independent, and creative behavior.

   Topics:

   basic concepts of biology including the characteristics of life, cell biology, heredity, evolution, diversity of living things, animal structures and functions, plant structures and functions, Indonesian biodiversity, and human interaction with other living things and the environment, ecological principles, conservation, biotechnology.

   References:

   1. Campbell, N.A. & J.B. Reece., L.A.Urry., M.L. Chain., S.A. Wasserman., P.V. Minorsky., D. Ferry., and R.B. Jackson, *Biology* 9th ed., Pearson Education, Inc., San Francisco, 2010.
   2. Johnson, G.B, *The living world*, Wm.C. Brown Publishers, Dubuque, 1995.
   3. Starr, C. & R. Taggart, *Biology*: *The unity and diversity of life* 8th ed., Wadsworth Publishing Company, Belmont, 1998.

2. **General Chemistry**

   Code/Credit/Prerequisite: SCCH601101/2 credits/-

   Course Learning Outcome:

   Describe matter and its constituent components, the properties of matter and its changes, the history of the development of atomic theories and electron configuration, use chemical reaction stoichiometry and the mole concept in explaining the properties of matter and its changes.

   Topics:

   Matter and its changes, the components of atom, ions and molecules, atomic electronic structure, stoichiometry, major chemical reactions, kinetic theory of gases, solutions and colligative properties, thermochemistry, field integration, integrated science.

   References:

   1. L. Brown and Bursten, *Chemistry: The Central Science,* Prentice Hall, NJ,
   2. Silberberg, *Chemistry: The Molecular Nature of Matter and Change,* Mc-Graw Hill, 5ed.
   3. J.E. Brady, *General Chemistry: Principles & Structure*, John Wiley & Sons

3. **Introduction to Data Science**
   Code/Credit/Prerequisite: SCMF600002/2 credits/-
   Course Learning Outcome:
   Collecting and processing data.
   Topics:
   An explanation of what data science is and what skills are required to become a data scientist, some probability distributions commonly used in statistical modeling, applying several statistical tools (plots, graphs, numerical summaries) for data exploration, hypothesis testing (1 sample, 2 samples, k-sample), applying basic machine learning algorithms (linear regression & k-means), application of simple data exploration and data science processes in case study. Application of R for data processing.
   References:
   1. Cathy O'Neil and Rachel Schutt. Doing Data Science, Straight Talk from the Frontline. O'Reilly. 2014.
   2. Wickham, H., & Grolemund, G. (2016). R for data science: import, tidy, transform, visualize, and model data. "O'Reilly Media, Inc."; Grolemund, G., & Wickham, H. (2018). R for data science.
   3. Foster Provost and Tom Fawcett. Data Science for Business: What You Need to Know about
   4. Data Mining and Data-analytic Thinking. ISBN 1449361323. 2013
   5. Walpole, R. E., Myers, R. H., Myers, S. L., & Ye, K. (1993). Probability and statistics for engineers and scientists (Vol. 5). New York: Macmillan.

4. **Calculus 1**
   Code/Credit/Prerequisite: SCMA601001/3 credits/-
   Course Learning Outcome:
   Being able to explain the basic concepts of calculus.
   Topics:
   Introduction: Real Number Systems, Inequalities and absolute prices; One Variable Function: Definitions and Types of functions, Graphs (Cartesian, polar, parameter), Operations on Functions; Limits: Definitions and Theorems of Limits, Continuity; Derivatives of Functions: Definitions, Geometric Meaning, Derivative Formulas, Chain Rules, Higher Order Derivatives, Implicit Derivatives, Applications of Derivatives: Maximum and Minimum, Mean value theorem; Integral: Definition, Indefinite and definite integrals, Basic theorem of calculus, Basic properties of integrals, Integral Applications: Area and Volume of Rotating Object, Transcendent and Inverse Functions: Logarithmic Functions, Exponential, Trigonometric, Hyperbolic, Integration Techniques: Substitution Techniques, Partial Integral, Trigonometric integrals, Rationalizing substitution, Integrals of Rational Functions.

References:
1. D. Varberg & E.S Purcell, 9th ed, Calculus, 2007, Prentice-Hall.
2. G.B Thomas & R.L Finney, Calculus and Analytic Geometry, 9th ed, 1996, Addison-Wesley.

5. **Calculus 2**
Code/Credit/Prerequisite: SCMA601002/3 credits/Calculus 1
Course Learning Outcome:
Being able to explain the basic concepts of calculus.
Topics:
Indeterminate forms and improper integrals, Parametric Equations, Polar Coordinates, Area in Polar Coordinates; Integral Applications: Curve Length and Surface Area of Rotating Object; Multiple Variable Functions: Limits, Differentiability, Partial Derivative, Descendant, Directional Derivative, Tangent Plane, Maximum and Minimum; Double and Trifold Integral, Jacobian; Real Sequences.
References:
1. D. Varberg & E.S Purcell, 9th ed, Calculus, 2007, Prentice-Hall.
2. G.B Thomas & R.L Finney, Calculus and Analytic Geometry, 9th ed, 1996, Addison-Wesley.

6. **Elementary Linear Algebra**
Code/Credit/Prerequisite: SCMA601120/2 credits/-
Course Learning Outcome:
Explain the basic concepts of linear algebra with an emphasis on computation/calculation.
Topics:
Linear equation system; determinant; vectors in R^2 and R^3; Euclid's room; common vector space.
References:
1. Howard Anton, *Elementary Linear Algebra*, 9th ed., John Wiley, 2005.
2. Paul R. Halmos, *Finite Dimensional Vector Spaces*, Springer Verlag, New York, 1987.

7. **Basic Physics 1**
Code/Credit/Prerequisite: SCPH601101/4 credits/-
Course Learning Outcome:
After completing this course, when faced with basic physics problems in the fields of mechanics, vibrations, and simple and well-defined thermodynamics, first-year

students of the first semester are able to apply the principles and concepts of mechanics, vibrations, and thermodynamics to formulate solutions.

Topics:

Units, Magnitudes and Vectors, Motion along a Straight Line, Motion in Two and Three Dimensions, Newton's Law of Motion, Newton's Law Applications, Work and Kinetic Energy, Potential Energy and Conservation of Energy, Momentum, Impulses and Collisions, Rotation of Firm Objects, Dynamics of Rotational Motion, Oscillatory motion: simple and damped harmonic motion, Balance and Elasticity, Gravity, Fluid Mechanics, Temperature, Heat, Gas Kinetic Theory, First Law of Thermodynamics, Heat Engines, Entropy, and Second Law of Thermodynamics.

References:

1. Halliday, Resnick, and Walker, *Principles of Physics 10th Edition*, Wiley, 2014.
2. Serway Jewett, *Physics for Scientists and Engineers 9th Edition*, Thomson Brooks/Cole, 2014.
3. Giancoli, *Physics for Scientists and Engineers 7th Edition*, Pearson, 2014

8. **Basic Physics 2**

Code/Credit/Prerequisite: SCPH601201/4 credits/Basic Physics 1

Course Learning Outcome:

After completing this course, when faced with basic physics problems in the fields of electricity & magnetism , waves, and simple and well-defined optics , first year first semester students are able to apply the principles and concepts of electricity & magnetism , waves, and optics to formulate the solution.

Topics:

Electric Charge and Electric Fields, Gauss Law, Electric Potential, Capacitors and Dielectrics, Electric Current, Resistance and Direct Current, Magnetic Fields and Magnetic Force, Magnetic Field Sources, Electromagnetic Induction, Inductance, Electromagnetic Oscillation, Alternating Current, Maxwell's Equations , Mechanical Waves, Sounds, Standing Waves, Nature and Propagation of Light, Polarization of Light, Superposition & Interference of Light Waves, Diffraction of Light Waves, Optical Geometry, Optical Instruments.

References:

1. Halliday, Resnick, and Walker, *Principles of Physics 10th Edition*, Wiley, 2014.
2. Serway Jewett, *Physics for Scientists and Engineers 9th Edition*, Thomson Brooks/Cole, 2014.
3. Giancoli, *Physics for Scientists and Engineers 7th Edition*, Pearson, 2014

9. **Basic Physics Laboratory Work 1**

Code/Credit/Prerequisite: SCPH601142/1 credit/-

Course Learning Outcome:

make calculations, graphs, analyzes and conclusions based on the results of basic physics experiments, which include electricity, magnetism and optics so that they can explain basic physics concepts through experiments and theories.

Topics:

Electricity-Magnets: electrolysis, Wheatstone bridge, Kirchhoff's law, earth magnetic field, temperature coefficient, AC - RLC circuit, internal resistance, transformer, ohmic material, RC transient circuit, diode; Optics: polarimeters, optical geometry in lenses, photometry, prism refractive index, spectrometer, Newton rings, diffraction grating, standing waves.

References:

1. Book titled *Basic Physics Laboratory Work Guidelines*, UPP IPD, 3rd ed.2010.
2. Giancoli, DC., *Physics: Principle with Applications*, 6th ed., Prentice Hall, 2005.

10. **Basic Physics Laboratory Work 2**

Code/Credit/Prerequisite: SCPH601242/1 credit/ Basic Physics 1, Basic Physics Laboratory Work 1

Course Learning Outcome:

Make calculations, graphs, analyzes and conclusions based on the results of basic physics experiments, which include Mechanics and Heat so that they can explain basic physics concepts through experiments and theory.

Topics:

Measurement technique; Mechanics: moment of inertia, free fall motion, density of liquid, friction coefficient, collision, torsional pendulum, viscosity of liquid, Young's modulus, simple pendulum, surface tension, hardness test; Heat: linear expansion coefficient, thermal conductivity, calorimeter, Joule constant, solar collector, ideal gas law, Newton cooling, radiation constant, absorption of radiation energy.

References:

1. Book titled *Basic Physics Laboratory Work Guidelines*, UPP IPD, 3rd ed.2010.
2. Giancoli, DC., Physics: Principle with Applications, 6th ed., Prentice Hall, 2005.

11. **Mathematical Methods in Physics 1**

Code/Credit/Prerequisite: SCPH601213/4 credits/Calculus 1

Course Learning Outcome:

Apply mathematical methods in the form of vector analysis, tensor analysis, and ordinary differential equations to second order linear in physics problems.

Topics:

Vector differentials (gradient, divergence, curl, and Laplacian), vector integrals, Gauss and Green's theorem, Stokes' theorem, Kronecker and Levi-Civita delta tensor operations, 1st order ordinary differential equations, exact differential equations, second order ordinary differential equations, transformations Laplace, Dirac delta function.

References:

1. M.L. Boas, *Mathematical Methods in the Physical Sciences*, 3rd Ed, John Wiley and Sons, 2006.
2. G.B. Arfken and H.J. Weber, *Mathematical Methods for Physicists*, 5th Ed, Hartcourt Academic Press, 2001.

12. **Mathematical Methods in Physics 2**

Code/Credit/Prerequisite: SCPH602111/4 credits/Calculus 2, Mathematical Methods in Physics 1

Course Learning Outcome:

Apply mathematical methods in the form of complex variable functions, Fourier series, and calculus of variations in physics problems.

Topics:

Complex functions, Cauchy-Riemann theorem, Laurent series, Cauchy contour integrals, residue theorems, conformal mappings, Fourier series and coefficients, Dirichlet conditions, Parseval theorem, Fourier transforms, Euler's equations in calculus of variations, brachistochrone, geodesic, minimum area, Hamilton principle (principle of minimum action), the Euler-Lagrange equation with constraints.

References:

1. M.L. Boas, *Mathematical Methods in the Physical Sciences*, 3rd Ed, John Wiley and Sons, 2006.
2. G.B. Arfken and H.J. Weber, *Mathematical Methods for Physicists*, 5th Ed, Hartcourt Academic Press, 2001.

13. **Mathematical Methods in Physics 3**

Code/Credit/Prerequisite: SCPH602112/2 credits/Calculus 2, Mathematical Methods in Physics 1

Course Learning Outcome:

apply mathematical methods in the form of special functions and partial differential equations in physics problems. Mathematical methods in the form of complex variable functions, Fourier series, and calculus of variations in physics problems.

Topics:

Error function, Gamma function, Beta function, Stirling formula, Legendre equation, Rodrigues formula, Legendre series, associated Legendre polynomial, Bessel equation, second type Bessel function, Hermite function, Laguerre function, method of variable separation in partial differential equations, Poisson's equation, Green function, integral transformation method.

References:

1. M.L. Boas, *Mathematical Methods in the Physical Sciences*, 3rd Ed, John Wiley and Sons, 2006.
2. G.B. Arfken and H.J. Weber, *Mathematical Methods for Physicists*, 5th Ed, Hartcourt Academic Press, 2001.

14. **Electronics 1**

Code/Credit/Prerequisite: SCPH601254/2 credits/Basic Physics 1

Course Learning Outcome:

Describe the principles of discrete electronics: power supply, diode, bipolar transistor, field effect transistor and operational amplifier and be able to apply them in electronic system design.

Topics:

Power Supplies, Semiconductors, Diode Theory and Diode Circuits, Special Purpose Diodes, Bipolar-Junction Transistors (BJT), Transistor Planning, Transistor Basic Amplifier Circuits, Power Amplifiers, Junction Field Effect Transistors (JFET), MOSFET , Operational Amplifier (Op-Amp) Basic Structure and its characteristics, Linear Op-Amp Circuits: Inverting and Non-inverting Amplifiers, Summing Amplifiers, DC Imperfections, Differential Amplifiers, Instrumentation Amplifiers, Voltage-Controlled Current Sources (VCCS), Operational Op-Amp with Single-Supply, Active Filters, Nonlinear Op-Amp Circuits: Comparators, Integrators, Differentiators, Active Diode Circuits, Oscillators and Directional Power Supplies.

References:

1. A. P. Malvino and D. J. Bates, Electronic Principles, 8th edition, McGraw-Hill Book Co., 2015
2. T.L. Floyd and D.M. Buchla, Analog Fundamentals; A System Approach, Pearson Prentice-Hall, 2013
3. L. M. Faulkenberry, An Introduction to Operational Amplifiers, with Linear Applications, 2nd edition, John Wiley & Sons, 1982.

15. **Electronics 2**

Code/Credit/Prerequisite: SCPH602156/2 credits/Electronics 1, Electronics Laboratory Work 1

Course Learning Outcome:

Explain the principles of digital electronics and be able to apply them in the latest electronic system design methods.

Topics:

Introduction to Digital Electronics, Digital Number Systems, Basic Logic Gates, Introduction to Digital Electronics Circuit Design with VHDL, Programmable Logic Devices: CPLDs, FPGAs with VHDL. Combination Logic Series and Simplification Methods: Boolean Algebra, Karnaugh Diagram, Quine McCluskey Tabulation

Method. Arithmetic Circuits, Circuit Design with MSI ICs: Decoders, Encoders, Multiplexers and Demultiplexers, Magnitude Comparators, Digital Electronics Family (DDL, TTL, CMOS, ECL), characteristics and interfacing. Flip-Flop and their Applications: Shift Registers, Asynchronous (Ripple) Counter, Synchronous (Parallel) Counter, Algorithmic State Machines (ASM) or Finite Sate Machine (FSM), Multivibrator and 555 Timer, ADC and DAC, Basics of Microprocessors and Microcontrollers 8051.

References:

1. W. Kleitz, Digital Electronics, A Practical Approach, 9th edition, Prentice Hall, 2012.

2. R. J. Tocci, N.S. Widmer, G.L. Moss, Digital Systems; Principles and Applications, Pearson Prentice-Hall, 2015.

3. J. Bignell, R. Donovan, Digital Electronics, 5th edition, Delmar Cengage Leraning, 2006.

16. **Electronics Laboratory Work 1**

Code/Credit/Prerequisite: SCPH601245/1 credit/Basic Physics 1, Basic Physics Laboratory Work 1

Course Learning Outcome:

Apply the principles of discrete electronics and operational amplifiers: diodes, transistors, Field Effect Transistors (FET), Op-Amp to analyze and design electronic circuit systems.

Topics:

Use of measuring instruments and testing of electronic components, diodes; characteristics, diode application and Zener diodes, transistors; transistor circuits, transistor applications and FET characteristics, Operational Amplifier characteristics; Inverting op-amps, non-inverting op-amps and summing op-amps, mathematical operation circuits of operational amplifiers; Inverting, Scalling and Adder-Subtracter Amplifier, Op-Amp-based Active Filter; Differentiators, Integrators, Low-pass and High-pass Filters, Non Linear Operational Amplifiers, Operational Amplifier-based Sensors and Amplifiers, Project Tasks and Project Presentations.

References:

1. A. P. Malvino, D. J. Bates, *Experiments Manuals for Electronic Principles*, 7th ed, McGraw-Hill Co., 2006.

2. A. P. Malvino, D. J. Bates, *Electronic Principles*, 8th ed, McGraw-Hill Book Co., 2015.

17. **Electronics Laboratory Work 2**

Code/Credit/Prerequisite: SCPH602147/1 credit/Electronics 1, Electronics Laboratory Work 1

Course Learning Outcome:
apply digital electronics principles to analyze and design digital electronic circuit systems.
Topics:
Basic logic gate circuits, Combinatorial digital electronics circuits, Boolean Algebra Applications and Karnaugh Maps, Encoders, Decoders, Multiplexers, Demultiplexers, Flip-Flops, Counters, Shift registers, Arithmetic Circuits, VHDL for Combinatorial Circuits, VHDL for Encoders, Decoders, Multiplexer, Demultiplexer, Flip-Flop and Counter, VHDL for FSM, Project Tasks and Project Presentations.
References:
1. W. Kleitz, Digital Electronics, A Practical Approach, 9th edition, Prentice Hall, 2012.
2. R. J. Tocci, N.S. Widmer, G.L. Moss, Digital Systems; Principles and Applications, Pearson Prentice-Hall, 2015.

18. **Measurement Physics**
Code/Credit/Prerequisite: SCPH602258/2 credits/Electronics 1
Course Learning Outcome:
explain the concept and the principle of physical measurements to study experimentally in the laboratory.
Topics:
measurement system (architecture, error, standards used in measurement), coherent noise and interference in measurement, physical principles of sensing, sensor characteristics, DC Null measurement, AC Null measurement, signal conditioning, digital techniques in mechanical measurement, readout and data processing, examples of measurement system design
References:
1. Jacob Fraden, Handbook of Modern Sensors: Physics, Designs, and Applications, 3ed, Springer-Verlag New York, Inc. 2004.
2. T. G. Beckwith, R. D. Marangoni, and J. H. Lienhard V, *Mechanical Measurements (I. Fundamentals of Mechanical Measurement, II. Applied Mechanical Measurements)*, Addison-Wesley Publishing Company, 5ed, 1993.
3. Robert B. Northrop, Introduction to Instrumentation and Measurements, Taylor & Francis, 2ed, 2005.

19. **Modern Physics**
Code/Credit/Prerequisite: SCPH602133/3 credits/Basic Physics 2, Calculus 2, Mathematical Methods in Physics 1
Course Learning Outcome:

formulate simple and well-defined solutions to modern physics problems, including relativity, particle-wave dualism, quantum physics, atoms and molecules, and statistical physics.

Topics:

Special relativity theory; the particle-wave duality: particle-like properties of electromagnetic waves and wave-like properties of matters; quantum mechanics; atomic physics: models of the hydrogen atom, 3-dimensional hydrogen atom and many-electron atom; molecule; statistical physics.

References:

1. S. P. Thornton and A. Rex, , Modern Physics 3rd ed., Thomson Brooks/Cole, 2006.
2. K. Krane, Modern Physics 3rd ed, Wiley, 2012.
3. R. Harris, Modern Physics 2nd ed., Pearson, 2008.
4. J. Bernstein, P. M. Fishbane, and S. Gasiorowicz, Modern Physics, Prentice Hall, 2000.

20. **Advanced Physics Laboratory Work 1**

Code/Credit/Prerequisite: SCPH602144/1 credit/Basic Physics Laboratory Work 2.

Course Learning Outcome:

carry out simple Modern Physics experiments and analyze the results.

Topics:

Torsional oscillator, magnetic torsion, microwaves, Faraday rotation, electric Kerr effect, Hall effect on metals, Hall effect on semiconductors, ferromagnetic hysteresis.

References:

1. J.P Holman, *Experimental Method for Engineers*, 7th ed., McGraw-Hill Book, Inc., 2001
2. Ogawa Seiki, *Instruction Manual: Franck-Hertz demonstration*, OGAWA SEIKI, Tokyo Central PO Box No.1618 Tokyo, Japan, 1987.
3. Ogawa Seiki, *Instruction Manual: e/m Demonstration Apparatus*, OGAWA SEIKI, Tokyo Central PO Box No.1618 Tokyo Japan, 1987
4. Leybold-Heraeus, *Physics Experiment*, vol. 1, 2 & 3, Leybold GmBH, 1986.
5. Krane, Kenneth, *Modern Physics*, 2nd ed., Mc Graw Hill, 1996.
6. H.D. Resnick and J. Walker, *Fundamental of Physics,* 6th ed., John Wiley & Son, Inc, 2001.
7. Pasco *Heat conduction Apparatus*, Instruction Manual 012-09189A, www.pasco.com, 2012.
8. Teach Spin, *Faraday Rotation*, *Guide to the experiment*, Teach Spin.Inc., Tri-Main Centre-Suite 409, 2495 Main Street.Buffalo, NY 14214-2153, 2012

21. **Advanced Physics Laboratory Work 2**

Code/Credit/Prerequisite: SCPH602246/1 credit/ Advanced Physics Laboratory Work 1, Modern Physics.

Course Learning Outcome:

carry out simple Modern Physics experiments and analyze the results.

Topics:

Electron Spin Resonance (ESR), Nuclear Magnetic Resonance (NMR), Thompson Tube, Rutherford Scattering, Frack-Hertz effect, Zeeman effect, Thermal radiation, radioactive decay and half-life.

References:

1. J.P Holman, *Experimental Method for Engineers*, 7th ed., McGraw-Hill Book, Inc., 2001

2. Ogawa Seiki, *Instruction Manual: Franck-Hertz demonstration*, OGAWA SEIKI, Tokyo Central PO Box No.1618 Tokyo, Japan, 1987.

3. Ogawa Seiki, *Instruction Manual: e/m Demonstration Apparatus*, OGAWA SEIKI, Tokyo Central PO Box No.1618 Tokyo Japan, 1987

4. Leybold-Heraeus, *Physics Experiment*, vol. 1, 2 & 3, Leybold GmBH, 1986.

5. Krane, Kenneth, *Modern Physics*, 2nd ed., Mc Graw Hill, 1996.

6. H.D. Resnick and J. Walker, *Fundamental of Physics,* 6th ed., John Wiley & Son, Inc, 2001.

7. Pasco *Heat conduction Apparatus*, Instruction Manual 012-09189A, www.pasco.com, 2012.

8. Teach Spin, *Faraday Rotation*, *Guide to the experiment*, Teach Spin.Inc., Tri-Main Centre-Suite 409, 2495 Main Street.Buffalo, NY 14214-2153, 2012

22. **Thermodynamics**

Code/Credit/Prerequisite: SCPH602135/3 credits/ Basic Physics 2, Calculus 2, Mathematical Methods in Physics 1

Course Learning Outcome:

Describe the basic concepts of thermodynamics (the 0th to 3rd law of thermodynamics) from empirical reviews and extensions of mathematical formulations, and their use in various thermodynamic systems.

Topics:

The concept of equilibrium and the 0th law of thermodynamics, equations of state, the 1st law of thermodynamics and its consequences, entropy and the 2nd law of thermodynamics, the combination of the 1st and 2nd law of thermodynamics, thermodynamic potentials and the 3rd law of thermodynamics, thermodynamic applications on a variety of simple systems, Kinetic theory, transport phenomena, statistical thermodynamics, statistical applications in various gas system.

References:

1. F. W. Sears and L. G. Salinger, *Thermodynamics, Kinetic Theory, and Statistical Thermodynamics* 3rd Ed., Addison-Wesley Publishing Company, 1975
2. Zemansky, Dittman: Heat and thermodynamics 7th ed Mc Graw-Hill 1997

23. **Electromagnetic Field 1**

Code/Credit/Prerequisite: SCPH602221/3 credits/Basic Physics 2, Mathematical Methods in Physics 2 & 3

Course Learning Outcome:

Apply the concept of time-independent electromagnetic field (static and steady) in solving physics problems related to electricity and magnetism.

Topics:

Electrostatics, solutions to electrostatic problems, electrostatic fields in the dielectric medium, electrostatic energy, electric currents, magnetic fields from steady currents, magnetic properties of matter, magnetic energy, electromagnetic induction.

References:

1. J.R. Reitz, F.J. Milford, and R.W. Christy, *Foundations of Electromagnetic Theory*, 4th edition, Addison Wesley, 1993.
2. J. Vanderlinde, *Classical Electromagnetic Theory* 2nd ed, Kluwer Academics Publishers, 2005.
3. R. K. Wangness, *Electromagnetic Fields*, Willey, 1986
4. H. J. W. M. Kirsten, Electrodynamics: *An Introduction Including Quantum Effects*, World Scientific, 2004.
5. D.J. Griffiths, *Introduction to Electrodynamics*, 3rd edition, Prentice Hall, 1999.

24. **Electromagnetic Field 2**

Code/Credit/Prerequisite: SCPH603121/3 credits/Electromagnetic Field 1

Course Learning Outcome:

Implement the concepts and principles that apply to time-dependent electromagnetic field in solving physics problems involving electromagnetic interactions.

Topics:

Maxwell's equations, continuity equations, energy and momentum tensors, Poynting vectors, gauge transformations, electromagnetic waves, energy and momentum of electromagnetic waves, reflection and refraction, waveguides, Lienard-Wiechert potential, moving charge fields, dipole radiation, accelerated charge radiation, Special Relativity, and the covariant form of Maxwell's equations.

References:

1. J.R. Reitz, F.J. Milford, and R.W. Christy, *Foundations of Electromagnetic Theory*, 4th edition, Addison Wesley, 1993.
2. J. Vanderlinde, *Classical Electromagnetic Theory* 2nd ed, Kluwer Academics Publishers, 2005.

3. Roald K Wangness, Electromagnetic Fields, Willey, 1986
4. Harald J W Muler Kirsten, Electrodynamics: An Introduction Including Quantum Effects, World Scientific, 2004
5. D.J. Griffiths, *Introduction to Electrodynamics*, 3rd edition, Prentice Hall, 1999.

25. **Classical Mechanics**
Code/Credit/Prerequisite: SCPH602223/4 credits/ Basic Physics 2, Mathematical Methods in Physics 2 & 3
Course Learning Outcome:
apply the concept of classical mechanics in solving dynamic physics problems.
Topics:
Newtonian Mechanics-single particle, Gravity, Non-linear Vibration, Multiple Calculus of Variation Methods, Lagrange Mechanics, Hamilton Equation, Central Force, Particle System Dynamics, Motion in Non-inertial Terms of Reference, Rigid Body Dynamics.
References:
1. S.T. Thornton and J.B. Marion, *Classical Dynamics of Particles and Systems*, 5th ed, Thomson Brooks/Cole, 2004.
2. V. Barger and M. Olsson, *Classical Mechanics: A Modern Perspective*, 2nd ed, McGraw-Hill, 1995.

26. **Quantum Physics 1**
Code/Credit/Prerequisite: SCPH602222/4 credits/Elementary Linear Algebra, Modern Physics, Mathematical Methods in Physics 2 & 3
Course Learning Outcome:
explain the basic concepts of quantum mechanics and apply them to simple quantum systems and atoms such as hydrogen.
Topics:
black body radiation, photoelectric effect, Compton scattering, wave-particle duality, Bohr atoms, deBroglie waves, correspondence principle, wave packets, Heisenberg uncertainty principle, Schrödinger equation, wave function, probability interpretation, normalization, expected value, operator, commutation relationship, stationary state, eigenvalues and eigenfunctions, linear operators, hermiticity, expansion theorem, free-wave normalization, parity, degeneration, Dirac notation, representations, one-dimensional potential problems, simple harmonic oscillators and "ladder" operators, changes in the expected value of time, operator dependence on time, Schrödinger view and Heisenberg view, N-particle system, central force, Schrödinger equation in three dimensions, angular momentum, atoms such as hydrogen.
References:
1. S. Gasiorowicz, *Quantum Physics* 2nd Ed., John Wiley & Sons, Inc., 1996.

2. A. Goswami, *Quantum Mechanics* 2nd Ed., Wm. C. Brown Publishers, 1997.

27. **Quantum Physics 2**

Code/Credit/Prerequisite: SCPH602122/3 credits/Quantum Physics 1

Course Learning Outcome:

explain the implications of the interaction of charged particles and electromagnetic field, the concept of spin, and the perturbation theory for solving non-relativistic quantum mechanical problems.

Topics:

interaction of charged particles and electromagnetic field, gauge transformations, minimal substitution, matrix mechanics, spin, base and representation, summation of angular momentum, the Clebsch-Gordan coefficient, spectroscopic notation, parity and orbital angular momentum, time-independent perturbation theory: non-degeneration and degeneration, realistic hydrogen atoms, helium atoms, atomic structures, molecules, time-dependent perturbation theory, scattering theory, density matrices: pure and mixed states.

References:

1. S. Gasiorowicz, *Quantum Physics*, John Wiley & Sons, Inc., 1996.
2. A. Goswami, *Quantum Mechanics 2nd Ed.*, Wm. C. Brown Publishers, 1997.

28. **Computational Physics**

Code/Credit/Prerequisite: SCPH602214/4 credits/ Elementary Linear Algebra, Mathematical Methods in Physics 2 & 3

Course Learning Outcome:

apply the basics of programming algorithms and numerical methods using Matlab/Octave/Scilab software or similar, to solve physics problems in algebraic or calculus forms.

Topics:

Introduction to programming algorithms, introduction to Matlab/Octave/Scilab, introduction to matrices and numerical matrix operations, solutions to root functions with the bisection method, False-Position and Newton-Raphson, solutions to linear equation system using the Gauss elimination method, LU decomposition and Jacobi's iteration, fitting using the least-square method, lagrange interpolation and cubic spline, solutions to eigenvalue problems using the power and QR methods, numerical differentiation of orders 1 and 2 with finite difference method, numerical integration using trapezoid, Simpson and Gaussian Quadrature methods: Gauss-Lagrange, solution to differential equations with initial conditions using the Euler and Runge-kutta 4th order method, solution to ordinary and partial differential equations (elliptic, parabolic, and hyperbolic) with boundary conditions with the finite difference approach method.

References:

1. R.L Burden and J. Douglas Faires, Numerical Analysis, 9th, Cengage Learning, 2015
2. A. Gilat and V. Subramaniam, Numerical Methods for Scientists and Engineers, 3th, John Wiley & Sons, 2014
3. A. Quarteroni, F. Saleri, P. Gervasio, Scientific Computing with Matlab and Octave, 3th, Springer, 2010
4. S. J. Chapra and R.P. Canale, Numerical Methods for Engineers, 6th, Mc. Graw Hill, 2009

29. **Vibrations & Waves**

Code/Credit/Prerequisite: SCPH602235/3 credits/ Basic Physics 2, Mathematical Methods in Physics 2 & 3

Course Learning Outcome:

Apply the concepts and principles of vibration and waves in solving physics problems in vibrations and waves.

Topics:

Simple, damped, and forced harmonic vibrations; Combined/coupled oscillation; Transverse waves, longitudinal waves, waves in transmission cables, EM gels, 2 and 3 dimensional waves, waves in optical systems, wave interference, wave diffraction, and wave mechanics.

References:

1. H.J. Pain, *The Physics of Vibrations and waves,* 3rd edition John Wiley &Son
2. French, A. P. *Vibrations and Waves*. New York, N.Y, W.W. Norton & Company, ISBN: 9780393099362
3. Iain G, Main, *Vibrations and Waves in Physics,* Cambridge University Press, ISBN: 9780521447010

30. **Introduction to Solid State Physics**

Code/Credit/Prerequisite: SCPH603133/3 credits/Modern Physics

Course Learning Outcome:

formulate simple modern physics problem solving related to solids and well-defined.

Topics:

the structure of solids, vibration in solids/phonons, electronic structures, superconductivity, magnetism, dielectrics and ferroelectrics.

References:

1. R. K. Puri and V. K. Babbar, Solid State Physics, S. Chand & Company Ltd, 1997
2. C. Kittle, *Introduction to Solid State Physics* 8th Ed., Wiley, 2005.
3. J. R. Hook and H. E. Hall, *Solid State Physics* 2nd Ed, Wiley, 1991.
4. S. P. Thornton and A. Rex, *Modern Physics* 3rd Ed., Thomson Brooks/Cole, 2006.
5. K. Krane, *Modern Physics* 3rd Ed, Wiley, 2012.

6. R. Harris, *Modern Physics* 2nd Ed., Pearson, 2008.
7. J. Bernstein, P. M. Fishbane, and S. Gasiorowicz, *Modern Physics*, Prentice Hall, 2000.

31. **Statistical Physics**

Code/Credit/Prerequisite: SCPH603124/4 credits/Thermodynamics, Mathematical Methods in Physics 2 & 3

Course Learning Outcome:

Apply statistical principles, quantum mechanical concepts, and semiclassical approach, to systems consisting of many particles, to provide, microscopic explanation of commonly known macroscopic, thermodynamic principles and phenomena, and provide modeling procedures, microscopic systematic to predict various thermodynamic properties of a system.

Topics:

microcanonical ensemble, canonical ensemble, chemical potential, classical partition function, equipartition energy, Gibb paradox and entropy, ideal gas in large canonical ensemble, Maxwell distribution, diatomic gas, interacting gas, state density, relativistic system, black body radiation, Planck distribution, Debye model, Bose-Einstein distribution, Bose-Einstein condensation, fermion, Pauli paramagnetism, Landau diamagnetism, phase transition, liquid-gas transition, Ising's model, average field theory, Landau theory, first order phase transition, second order phase transition, Landau-Ginzburg theory.

References:

1. Reif, *Fundamentals of Statistical and Thermal Physics*, McGraw-Hill Book Company, 1985.
2. M. Guenault, *Statistical Physics*, Routledge, 1988.

32. **Introduction to Nuclear Physics**

Code/Credit/Prerequisite: SCPH603135/3 credits/Modern Physics

Course Learning Outcome:

describe the properties of the atomic nucleus, nuclear process, and the benefits of nuclear physics.

Topics:

Rutherford scattering, nuclear properties, binding energy, bonding fraction, surface effect, separation energy, core radius, semiempirical mass formula, core spin, core electric moment, core magnetic moment, core instability, radioactivity, core models, nuclear force, particle physics, fundamental interactions, quark model, nuclear astrophysics, accelerators, detectors, nuclear reactors, benefits of nuclear physics.

References:

1. P. E. Hodgson, E. Gadioli, E. Gadioli Erba, *Introductory Nuclear Physics*, Oxford U. Press, 2000.
2. W. E. Meyerhof, *Elements of Nuclear Physics*, McGraw-Hill Book Co., 1989.

33. **Seminar**

Code/Credit/Prerequisite: SCPH603166/2 credits/have obtained minimum 64 credits

Course Learning Outcome:

produce a final assignment research proposal with the writing procedure that is appropriate for scientific principles and UI guidelines, describe procedures for writing a scientific article, and know good scientific presentation.

Topics:

Writing research proposals, writing scientific articles by following scientific journals, effective presentation techniques in accordance with scientific rules, scientific ethics and publication.

References:

1. UI Rector Decree number 628/SK/R/UI/2008, on the Technical Guidelines for the Final Assignment Writing of the University of Indonesia Students, June 16, 2008.
2. Final Assignment Short Script document format, University of Indonesia Library, Desember 2012
3. R. Weissberg and S. Buker, *Writing Up Research; Experimental Research, Report Writing for Students of English*, Prentice-Hall, Inc, 1990.

34. **Thesis**

Code / Credit / Prerequisite: SCPH604261/6 Credit/have obtained minimum 114 credits

Course Learning Outcome:

compose thesis and scientific article, and defend them in presentation during the final assignment seminar.

Topics:

Research results.

References:

1. UI Rector Decree number 628/SK/R/UI/2008, on the Technical Guidelines for the Final Assignment Writing of the University of Indonesia Students, June 16, 2008.
2. UI Rector Decree number 2198/SK/R/UI/2013, on the Implementation of the Bachelor Degree Program in the University of Indonesia, November 1, 2013.
3. FMIPA UI Dean Decree number 111/UN2.F3.D/HKP.02.04/2014, on Thesis Completion Guidelines, September 8, 2014.

4. Final Assignment Collection Procedure S1 (Thesis), S2 (Tesis) and S3 (Dissertation), University of Indonesia Library, December 2012

<u>Elective Courses</u>

1. **Relativistic Quantum Mechanics**

   Code/Credit/Prerequisite: SCPH603700/4 credits/Quantum Physics 1

   <u>Course Learning Outcome:</u>

   apply the concepts and formulations of relativistic quantum mechanics to nuclear and particle problems.

   <u>Topics:</u>

   review of non-relativistic quantum mechanics, harmonic oscillators, Dirac operators, $\hat{a}$ and $\hat{a}^{\dagger}$, Dirac delta functions, time-independent perturbation theory, disharmonious oscillators, time-dependent perturbation theory, Fermi's golden rule, Rutherford scattering cross section, relativistic notation, natural units, Maxwell's equation in relativistic form, free photon wave equation, minimal substitution and its use to derive Lorentz force equation from free particle equation, Mandelstam variables *s*, *t*, and *u*, as well as cross-symmetry, Klein-Gordon equation, free particle solutions, charged particles in the electromagnetic field A^{μ}, the scattering amplitude of the point particle without spin with the electromagnetic field A^{μ}, the scattering amplitude of the two point particles without spin, the Compton scattering of the point particles without spin, the Coulomb scattering cross section of the point particle without spin, Feynman's rule for Coulomb scattering point particle without spin, Dirac equation and Dirac matrix γ^{μ}, properties and the algebra of the Dirac matrix γ^{μ}, the probability and density currents for Dirac particles, Dirac equations for free particles, Dirac's interpretation of negative energies, the scattering amplitude of Dirac particles with the electromagnetic field A^{μ}, the amplitude of the Coulomb scattering of two Dirac particles, Coulomb scattering cross-section of Dirac two particles, Feynman's rule for Dirac particle scattering, Compton scattering of Dirac particle.

   <u>References:</u>

   1. J. D. Bjorken and S.D. Drell, *Relativistic Quantum Mechanics*, McGraw-Hill, 1964.
   2. F. Halzen and A. D. Martin, *Quarks and Leptons*, John Wiley & Sons, 1984.

2. **Classical Field Theory**

   Code/Credit/Prerequisite: SCPH603701/3 credits/Electromagnetic Field I, Classical Mechanics

   <u>Course Learning Outcome:</u>

   explain fundamental classical fields, apply covariance formulations in Lagrangian classical field theory, and use mathematical instrument of curved space (non-Euclid) geometry to analyze gravitational field within the framework of the Theory of General Relativity as a phenomenon of space-time curvature.

Topics:

Lorentz transformations, algebra and tensor calculus, the covariance formulation of Maxwell's electromagnetic field, Lagrangian formulation and Minimum Action Principle for continuous system (field), Euler-Lagrange equations for Maxwell's field and scalar field (Klein-Gordon), Noether theorem, energy-momentum tensors, gauge transformations, gauge invariance for Abelian and non-Abelian symmetries, the equivalence of inertial mass and gravitational mass, tensor field and tensor calculus in uneven manifolds, metric tensors, Christoffel's symbol, covariance derivatives, geodesic equations, Riemann's curvature tensors, Ricci tensors, Einstein's equations for gravitational field, Schwarzschild solution, Reissner-Nordstrom solution, de Sitter and anti-de Sitter solutions, black holes, selected topics in cosmology.

References:

1. Lewis H. Ryder, *Introduction to General Relativity*, Cambridge University Press, 2009.

2. Sean M. Carroll, S*pacetime and Geometry: Introduction to General Relativity*, Addison-Wesley, 2004.

3. Moshe Carmeli, *Classical Fields: General Relativity and Gauge Theories*, John-Wiley and Sons, 1982.

3. Advanced Computational Physics

Code/Credit/Prerequisite: SCPH603702/3 credits/Computational Physics

Course Learning Outcome:

apply numerical approaches, create micro programming algorithms, and translate them into a computer program using the Fortran programming language or its equivalent, to solve physics problems.

Topics:

Root function search, solutions to linear equation system, fitting using the least-square method, interpolation, numerical integration, solutions to ordinary and partial differential equations with boundary conditions, solutions to eigenvalue problems using the power method, secular equation method.

References:

1. P. L. DeVries, *A First Course in Computational Physics*, John Wiley &Sons, Inc., New York, 1994.

2. W. H. Press, *et. al.*, *Numerical Recipes in Fortran 77*, 2nd Ed., Cambridge University Press, New York, 1992. (online/free download: http://www.nrbook.com/a/bookfpdf.php)

3. R. H. Landau & M. J. Paez, *Computational Physics: Problem Solving with Computers*, John Wiley & Sons, Inc., New York, 1997.

4. S. E. Koonin, *Computational Physics*, Addison-Wesley Publishing Co., Inc.,Redwood City, 1986.

4. Scattering Theory

Code/Credit/Prerequisite: SCPH604700/2 credits/Quantum Physics 1, Introduction to Core Physics

Course Learning Outcome:

describe the process of particle scattering according to non-relativistic quantum mechanics.

Topics:

scattering kinematics, wave scattering function, scattering amplitude, cross section, Born approach, Lippmann-Schwinger equation, propagator, scattering matrix, partial wave technique, phase shift, density matrix, spin quantity, numerical calculation to solve the Lippmann-Schwinger equation for the scattering matrix T.

References:

1. A. S. Davydov, *Quantum Mechanics*, 2nd Ed., Pergamon Press, 1976.
2. W. Glöckle, *The Quantum Mechanical Few-Body Problem*, Springer-Verlag, 1983.
3. R. L. Liboff, *Introductory Quantum Mechanics*, 2nd Ed., Addison-Wesley, Reading, Massachusetts, 1992.
4. M. E. Rose, *Elementary Theory of Angular Momentum*, Wiley, New York, 1957.

5. Particle and Nuclear Physics

Code/Credit/Prerequisite: SCPH604701/3 credits/Quantum Physics 1, Introduction to Core Physics

Course Learning Outcome:

Describe the phenomena and basic concepts of nuclear physics.

Topics:

measurement of mass and core geometry, types of particle detectors, particle accelerators and their current states; nuclear physics: Rutherford scattering, nuclear phenomena (global properties of the nucleus), core models (microscopic and collective types of models), nuclear radiation (alpha, beta and gamma decays); properties and interactions of elementary particles, the concept of symmetry and discrete transformations in particle physics, standard models for particle physics, confrontation of predictive standard models with experimental data, models outside the standard model of particle physics.

References:

1. A. Das and T. Ferbel, *Nuclear and Particle Physics*, World Scientific, 2003.
2. B. Povh, K. Rith, C. Scholz, F. Zetsche, *Particle and Nuclei, An Introduction to Physical Concepts*, Springer-Verlag, 2006.

6. **Angular Momentum Theory**
Code/Credit/Prerequisite: SCPH604702/2 credits/Quantum Physics 2
Course Learning Outcome:
explain the concepts related to angular momentum and apply them to systems with angular momentum.
Topics:
Operators and unitary transformations, diagonalization and operator exponential forms, definition of angular momentum, commutation relation and commutator eigenvalues, physical interpretation of angular momentum, summation of two angular momentums, definition of the Clebsch-Gordan coefficient, relations on the Clebsch-Gordan coefficient, calculation of the Clebsch-Gordan coefficient, symbols 3j, 6j and 9j, rotational operators and their orthogonality properties, spherical harmonic functions, irreducible tensors, Wigner-Eckart theorem, summation of two angular momentums, Racah coefficient, Maxwell's equation and multipole field in spherical form, static interactions and spin-1/2 interactions, application to nuclear system, emission of alpha particles by the nucleus.
References:
1. M. E. Rose, *Elementary Theory of Angular Momentum*, Dover Books on Physics, Reprint edition, 2011.
2. R. Edmonds, *Angular Momentum in Quantum Mechanics*, Princeton University Press, Reissue edition,1996.
3. A. de-Shalit and I. Talmi, *Nuclear Shell Theory*, Dover Publications, 2004.

7. **Introduction to Material Science**
Code/Credit/Prerequisite: SCPH603703/4 credits/Modern Physics and Introduction to Solid State Physics.
Course Learning Outcome:
explain the basics of material science and the application of physics to solve general problems in the field of materials.
Topics:
Overview of material science, types of materials, material process-properties-structure relationships, material structures (structures: macro, micro, sub, crystal and atomic electronic structure); atomic bonds in crystals, binding energy; unit cell; allotropy; crystal direction and plane; defects in crystals; materials: metals and alloys, ceramics, polymers, composites, electronic and magnetic materials.
References:
1. W.D. Callister, Jr. *Materials Science and Engineering: An Introduction,* 7th Ed, John Wiley & Sons, Inc., 2007.

8. Applied Materials Physics

Code/Credit/Prerequisite: SCPH603704/3 credits/Modern Physics, Advanced Physics Laboratory Work 1 & 2, and Introduction to Solid State Physics

Course Learning Outcome:

To give students the insight into the application of physics in materials with polymer, ceramics, metal, and composite bases, both conventional and progressive materials. Students understand the synthesis process, can determine physical properties, chemical properties and mechanical properties of materials and are able to characterize materials based on the principles of physics.

Topics:

Metals: The principle of mass conservation in the preparation of metal alloys; Induction melting, arc melting, mechanical alloying, powder metallurgy technologies for the preparation of metal alloys and blast furnace technology for metal reduction; Thermodynamic overview of the process of forming metal alloys (entropy and free energy); Solidification process; homogeneous, heterogeneous nucleation; nucleation rate, alloy system, solubility limit, Hume-Rothery rules; microstructure; Alloy system binary phase diagrams (miscibility gap, eutectic, eutectoid, peritectic, peritectoid, intermediate phase, intermetallic phase, lever rule); Ternary system phase diagram (introduction); Alloy system Fe-C (steel, hypo and hyper eutectoid steel, cast iron); Heat treatment process in the system; microstructural evolution; grain growth kinetics; recrystallization kinetics, mechanical and magnetic properties of alloy systems. The use of x-rays for phase identification, determination of the volume fraction of the phase in alloy systems.

Polymers: A basic concept of polymer science (difference in polymer physics and polymer chemistry). Describe the mechanism and kinetics of polymerization reactions (initiation, propagation, termination). Classification of polymers based on their properties: Thermoplastic, thermoset and elastomer. Polymer material synthesis techniques. Synthetic polymers: PVC, PS, PE (LDPE and HDPE), PP, PTFE, PMMA, PET, Nylon. Polymer morphology and characterization using SEM / TEM. Rheology and mechanical properties of polymers. Physical properties of polymer materials. Analysis of polymer thermal properties (DTA, TGA, DSC). Characterization of polymer mechanical properties (tensile strength, compressive strength, flexural strength, impact resistance, fatigue/fatigue, hardness, flexibility, Young's Modulus).

Ceramics : Effects of chemical bonds on physical properties, diffusion and electrical conductivity, formation, structure and properties of glass, sintering of solids, sintering of liquids and grain growth, mechanical properties, thermal properties, dielectric properties, magnetic properties and optical properties.

Composites: Introduction, various types of composites and their applications, various types of matrices and reinforcements, selection of matrix and reinforcement materials, matrix-reinforcing interfaces, mechanical properties of isotropic composites and Rule of Mixtures, as well as introduction of anisotropic models on uninterrupted fiber reinforcement.

References:

1. Peter Hassen, Physical Metallurgy, Cambridge University Press, London (ISBN: 0-521-29183-6)
2. Suryanarayana, Grant Norton, X-Ray Diffraction: Practical Approach, Plenum Press, New York and London (ISBN: 0-306-45744-X)
3. M. W. Barsoum, *Fundamentals of Ceramics*, Inst. of Publishing, 2003.
4. Stevens, M.P., 1975: Polimer Chemistry and Introduction, Addison Wesley, N.Y.
5. F.W. Billmeyer, JR. (1998) Textbook of Polymer Science, America: John Wiley & Sons, Inc.
6. Various selected journal articles.

9. Material Characterization Methods

Code/Credit/Prerequisite: SCPH603705/4 credits/Modern Physics, Advanced Physics Laboratory Work 1 & 2, and Introduction to Solid State Physics

Course Learning Outcome:

describe the principles of physics in various material testing instruments and apply various standard methods for testing and characterization of materials and be able to process data for the derivation of various material property quantities.

Topics:

The basic principles of X-Ray, XRD, XRF, TEM, SEM, EDS, DTA, TGA, DSC, UTM, Impact Test, LPSA, AAS, ESR. Permeameter, VSM. Various test standards (including ASTM E 975-95), material phase identification, heat capacity, thermal conductivity, APD program, Match and GSAS, mechanical properties testing and standardization, ultrasonic and its applications, radiography and its applications, Eddy Current technique and its applications, optical diffraction and its applications, magnetic properties and their standardization.

References:

1. B.D. Cullity, *Introduction to X-Ray Diffraction*, Addition Wesley, 1978
2. P.J. Goodhew and F.J. Humphreys, *Electron Microscopy and Analysis*, Taylor & Francis, 1988
3. ASM Handbook Volume 10, *Materials Characterization*, ASM International, 1992
4. Scientific publications related to material methods and characterizations.

10. Capita Selecta of Advanced Material

Code/Credit/Prerequisite: SCPH604703/4 credits/Introduction to Solid State Physics

Course Learning Outcome:

Introduce the development of synthesis and processing methods of various types of advanced materials engineered by materials including metals and their alloys, ceramic materials, composites, polymers and high- tech materials (electronic and magnetic) as well as the latest research developments in various advanced materials to help students explore and solve various material problems for the purpose of the final project.

Topics:

1. Permanent Magnet: The development of research and fabrication technology from time to time; 2. Selection of corrosion resistant alloys for implantation applications in the human body; 3. Polymer materials as an alternative to developing advanced materials that are environmentally friendly, lightweight and corrosion resistant for various applications; 4. Various magnetism phenomena in magnetic materials; 5. Micromagnetic models for computation of magnetization of various magnetic materials; 6. Intelligent materials: synthesis and characteristics of multiferoic materials and their applications in modern products; 7. Functional materials : potential candidates, phenomena, syntheses and applications; 8. Fabrication of ZnO nonorod-based thin films for optical sensor applications; 9. Composite material fabrication technology and fabrication techniques for various applications.

References:

1. Various selected journal articles.

11. Spectroscopy A

Code/Credit/Prerequisite: SCPH603709/2 credits/Modern Physics, Vibrations and Waves, Electromagnetic Field 1, Classical Mechanics

Course Learning Outcome:

describe atomic and molecular spectroscopy methods, including rotational, vibration, and electronic spectroscopy and analyze the experimental results of these spectroscopies, as well as elemental and surface analysis spectroscopy.

Topics:

interaction of electromagnetic waves with matter and experimental methods, rotational spectroscopy, vibration spectroscopy, electron spectroscopy, atomic spectroscopy and surface analysis spectroscopy.

.

References:

1. Collin N Banwell and Elaine M McCash, Fundamentals of Molecular Spectroscopy, 4th Ed., McGraw-Hill Book Co.,Singapore, 1995.

2. J. Michael Hollas, *Modern Spectroscopy* 4th Ed., John Wiley& Sons, Ltd., Chichester, 2004.
3. James W Robinson, Eillen M Skelly Frame, George M Frame II, Undergraduate Instrumental Analysis 6th. Ed., Marcell Dekker, New York, 2005.
4. David W. Ball, *The Basic of Spectroscopy,* SPIE Publications, Washington, 2001.

12. Spectroscopy B

Code/Credit/Prerequisite: SCPH604704/2 credits/Introduction to Solid State Physics, Quantum Mechanics 1, Vibrations and Waves, Thermodynamics

Course Learning Outcome:

describe magnetic spectroscopy methods, electron and nuclear spin resonance, as well as Moessbauer spectroscopy, mass spectroscopy, chromatography, scanning tunneling spectroscopy, thermal analysis and analyze the results of these spectroscopic experiments.

Topics:

Analytical characterization of matter with thermal and electromagnetic radiation, interactions with external fields and particles and their experimental methods, magnetic spectroscopy, electron spin resonance (ESR) spectroscopy, nuclear spin resonance (NMR) spectroscopy, Moessbauer spectroscopy, mass spectroscopy, chromatography (GC and HPLC) , scanning tunneling spectroscopy and thermal analysis.

References:

1. James W Robinson, Eillen M Skelly Frame, George M Frame II, Undergraduate Instrumental Analysis 6th. Ed., Marcell Dekker, New York, 2005.
2. Collin N Banwell and Elaine M McCash, Fundamentals of Molecular Spectroscopy, 4th Ed., McGraw-Hill Book Co., Singapore, 1995.
3. D.R. Vij, *Handbook of Applied Solid State Spectroscopy,* Springer, New York, 2006.
4. T. Hatakeyama, Z. Liu (Eds.), *Handbook of Thermal Analysis,* John Wiley and Son, Inc., New York, 1998.
5. G. Gauglitz and T. Vo-Dinh (Eds.), *Handbook of Spectroscopy,* Wiley-VCH Verlag GmbH & o, KGaA, Wienheim, 2003.

13. Methods of Quantum Field Theory for Solids

Code/Credit/Prerequisite: SCPH604705/3 credits/

Course Learning Outcome:

Explain the concept of quantum field theory and its application to calculating physical quantities related to the dynamics of electrons, phonons, and other quasi-particles in solid matter systems.

Topics:

The concept of quantum fields, Lagrangian and Euler-Lagrange equations, Schrodinger's equations and Dirac's equations as forms of Lagrange equations of motion, harmonic oscillators, second quantization, review of statistical physics of bosons and fermions, representation of occupational numbers, Green's function and field theory for fermions and bosons, Green function formalism for ground state (zero temperature), diagrammatic perturbation theory, Wick's theorem, Feynman diagram, Green function formalism for finite temperature, analytical continuation, single-band and multi-band tight-binding methods, linear response theory, Hubbard model, mean field theory, Mott metal-insulator transition, dynamic average field theory.

References:

1. Tom Lancaster and Stephen J. Blundell, *Quantum Field Theory for the Gifted Amateur*, Oxford University Press, 2014.
2. Alexander L. Fetter, John Dirk Walecka, *Quantum Theory of Many-Particle Systems*, Oxford, Dover Publications, 2003.
3. Alexandre Zagoskin, *Quantum Theory of Many-Body Systems: Techniques and Applications*, Springer, 2005.
4. Piers Coleman, *Introduction to Many-Body Physics,* Cambridge University Press, 2016.

14. Nano System Physics

Code/Credit/Prerequisite: SCPH604706/4 credits/

Course Learning Outcome:

Explain the concept of nano size, nanoparticles, nano system, physical phenomena that appear in materials with nanostructures, and their potential applications.

Topics:

Introduction to the nanoscale, quantum effects at the nanoscale, electronic and optical properties of nanoparticles, examples of self-assembled nanostructures: buckyballs, nanotubes, nanowires, quantum dots, nanocrystals, and some applications of nano system.

Nanomaterials and nanocomposites; nanomaterial surface properties, nanoparticle synthesis, nanomaterial mechanical properties, nanomaterial characterization.

References:

1. Amretashis Sengupta and Chandan Kumar Sarkar, *Introduction to Nano: Basics to Nanoscience and Nanotechnology,* Springer-Verlag Berlin Heidelberg, 2015.
2. Edward L. Wolf, *Nanophysics and nanotechnology: An introduction to modern concepts in nanoscience*, Wiley-VCH, 2006.
3. Michael Quinten, *Optical properties of nanoparticle systems*, Wiley-VCH, 2011
4. Nanomaterials: an Introduction to synthesis, properties and applications, 2nd ed, Dieter Vollath, Wiley, 2013.

15. Transport and Optical Properties of Materials

Code/Credit/Prerequisite: SCPH603706/4 credits/

Course Learning Outcome:

Explain the concept of the emergence of transport properties of charge and heat, as well as the optical properties of solids from a simple view of a free electron system to a more complex one with respect to the potential effects of crystals, phonons, etc.

Topics:

The transport properties of solids (energy band structure, electric charge transport phenomena, heat transport, electron beam by phonons, defects, and impurities, magneto-transport phenomena, two-dimensional electron gas, quantum wells and semiconductor superlattices, transport in low dimension system, optical properties (fundamental relationships in optical phenomena, Drude's theory, transitions between bands, joint density of states, absorption of light in solids).

References:

1. M.S. Dresselhaus, *Solid State Physics Part I - Transport Properties of Solids* (Lecture Note)
2. M.S. Dresselhaus, *Solid State Physics Part II - Optical Properties of Solids* (Lecture Note)
3. C. Kittel, *Introduction to Solid State Physics* 8th Ed., John Wiley & Sons, Inc., New York, 2005.
4. J. R. Hook and H. E. Hall, *Solid State Physics* 2nd Ed., John Wiley & Sons, Chichester, 1991.
5. N. W. Ashcroft and N. D. Mermin, *Solid State Physics*, Saunders College Publishing, Philadelphia, 1976
6. H. Ibach and H. Lüth, *Solid-State Physics* 4th Ed., Springer, New York, 2009

16. Magnetism

Code/Credit/Prerequisite: SCPH603707/2 credits/

Course Learning Outcome:

Explain the basic concepts of magnetism, the concept of magnetic moments, various phenomena of magnetic order in materials, quantum views of magnetism, and examples of applications of magnetic phenomena in modern technological devices.

Topics:

The basic concepts of magnetism, angular and spin magnetic dipole moments, paramagnetism, diamagnetism, ferromagnetism, antiferromagnetism, quantum view of magnetism, magnetic interactions, domains and domain walls, magnetism in metals, insulators, and semiconductors, magnetoresistance, magnons, spin-glass, superparamagnetism, application of magnetic phenomena to memory storage, Giant Magneto-Resistance (GMR), introduction of nanomagnetism and spintronics.

References:

1. S.J. Blundell, *Magnetism: A very Short Introduction*, Oxford University Press, 2012.
2. S.J. Blundell, *Magnetism in Condensed Matter Physics*, Oxford University Press, 2011.
3. C. Kittel, *Introduction to Solid State Physics* 8th Ed., John Wiley & Sons, Inc., New York, 2005.
4. *Nanomagnetism and Spintronics,* Edited by Teruya Shinjo, Elsevier, 2009.

17. Superconductivity

Code/Credit/Prerequisite: SCPH603708/2 credits/

Course Learning Outcome:

Explain the concept of superconductivity, physical phenomena in superconducting materials, superconductivity theory developments starting from the London theory to BCS theory, metal and ceramic superconductors, and some applications of superconductivity phenomena.

Topics:

History of the discovery of superconductors, superconducting properties, critical temperature, critical magnetic field, Meisner effect, London theory, Ginzburg-Landau theory, Cooper pair, BCS theory, some applications of superconductors: Magnetic Resonance Imaging (MRI), Superconducting Quantum Interference Device (SQUID).

References:

1. S.J. Blundell, *Superconductivity: A Very Short Introduction,* Oxford University Press, USA, 2009
2. Philippe Mangin and Rémi Kahn, *Superconductivity: An introduction,* Springer International Publishing, 2017.
3. Michael Tinkham*, Introduction to superconductivity*, McGraw Hill, 1996.

18. Sensors and Actuators

Code/Credit/Prerequisite: SCPH603710/2 credits/Electronics 2

Course Learning Outcome:

Describe the working principle of sensors and actuators, select and choose the right sensors and actuators for specific purposes, and applying them to monitor and measure physical quantities.

Topics:

Temperature Sensors (Thermistors, Resistance temperature sensors, Silicon resistive sensors, Thermoelectric sensors, PN junction temperature sensors, and Optical temperature sensors), Mechanical Sensors (pressure sensors, flow sensors, level sensors), Definition, classification, and characteristics of actuators; electric actuators; hydraulic actuators.

References:

1. Webster, John G., *The Measurement, Instrumentation and Sensors Handbook*, CRC Press, 1999.
2. Fraden, J., *GAIP Handbook of Modern Sensors, Physics, Designs and Applications*, J American Institute of Physics, 2004.
3. Beckwith, T. G., Marangoni, R. D. and J. H. Lienhard V, *Mechanical Measurements (I. Fundamentals of Mechanical Measurement, II. Applied Mechanical Measurements)*, Addison-Wesley Publishing Company, 6^{ed}, 2006.

19. Sensors and Actuators Laboratory Work

Code/Credit/Prerequisite: SCPH603711/1 Credit/Electronics 2

Course Learning Outcome:

Design electrical circuits for sensor and actuator applications and use them for monitoring and measuring physical quantities, making calculations, graphs, analyses and conclusions based on experimental results and explain the concepts of physics through experiments and theories.

Topics:

Electronic circuit designs and measurements using temperature sensors, pressure sensors, flow sensors, level sensors, proximity sensors, load sensors, light sensors, magnetic sensors, chemical sensors, electric actuators, hydraulic actuators and pneumatic actuators.

References:

1. Department of Physics of FMIPA UI, Laboratory Work Guidelines of Sensors and Actuators
2. Webster, John G., *The Measurement, Instrumentation and Sensors Handbook*, A CRC Handbook Published in Cooperation with IEEE Press, 1999.
3. Fraden, J., *GAIP Handbook of Modern Sensors, Physics, Designs and Applications*, J American Institute of Physics, 2004.
4. Beckwith, T. G., Marangoni, R. D. and J. H. Lienhard V, *Mechanical Measurements (I. Fundamentals of Mechanical Measurement, II. Applied Mechanical Measurements)*, Addison-Wesley Publishing Company, 6^{ed} , 2006.

20. Embedded Systems

Code/Credit/Prerequisite: SCPH603712/2 credits/Electronics 2

Course Learning Outcome:

Describe the principles of embedded system design, real-time operating systems, and programming and be able to apply them in embedded system application design.

Topics:

Introduction to Embedded Systems: definition of Embedded Systems, examples of embedded systems, microprocessors and microcontrollers; microcontroller architecture; memory organization; microcontroller based minimum system; Instruction sets; Parallel Input/Output; Interrupts; Counters and Timers; Analog to Digital Converter (ADC) and Digital to Analog Converter (DAC); Interfacing External Memory; Interfacing External Peripherals and Devices; Serial Data Communication: USART, SPI, I2C, 1-Wire; Multi-tasking and Real-time Operating Systems (RTOS); Connectivity and Networking: USB, Bluetooth, Zigbee, Controller Area Network (CAN).

References:

1. Mazidi, M.A., Naimi, S., *The AVR Microcontroller and Embedded Systems Using Assembly and C*, Prentice Hall, 2011.

2. Barnett, R. H., Cox, S., O'Cull, L., *Embedded C Programming and The Atmel AVR*, 2nd edition, Thomson Delmar Learning, 2007.

3. Noergaard, T., *Embedded Systems Architecture: A Comprehensive Guide for Engineers and Programmers*, Newnes Elsevier, 2005.

4. Catsoulis, J., *Designing Embedded Hardware*, O'Reilly, 2005.

21. Embedded Systems Laboratory Work

Code/Credit/Prerequisite: SCPH603713/1 Credit/Electronics 2

Course Learning Outcome:

Apply the principles of designing embedded system, operating system and its programming to analyze and design embedded system applications.

Topics:

Introduction to the minimum system of microcontrollers and programming in Assembly language and C language; Parallel Input/Output; Interrupts; Counters and Timers; Analog to Digital Converter (ADC) and Digital to Analog Converter (DAC); Interfacing External Peripherals and Devices: LCD, Keypad, Relay, DC Motor, Stepper Motor, Servo Motor, Real Time Clock (RTC); Serial Data Communication: USART, SPI, I2C, 1-Wire; Connectivity and Networking: USB, Controller Area Network (CAN).

References:

1. Mazidi, M.A., Naimi, S., *The AVR Microcontroller and Embedded Systems Using Assembly and C*, Prentice Hall, 2011.

2. Barnett, R. H., Cox, S., O'Cull, L., *Embedded C Programming and The Atmel AVR*, 2nd edition, Thomson Delmar Leraning, 2007.

3. Noergaard, T., *Embedded Systems Architecture: A Comprehensive Guide for Engineers and Programmers*, Newnes Elsevier, 2005.

4. Catsoulis, J., *Designing Embedded Hardware*, O'Reilly, 2005

22. Control System

Code/Credit/Prerequisite: SCPH603714/2 credits/Electronics 2

Course Learning Outcome:

Analyze and design control systems for continuous linear systems.

Topics:

Control System Analysis: introduction to the concept of feedback and control systems, Laplace transform, linear system transfer function, nonlinear system linearization, system mathematical modeling, mechanical and electrical systems, block diagram models, signal flow graph models, state variable models, error signal analysis , the sensitivity of the control system of feedback to the variation of the parameter control, Signal interference in the feedback control system, system transient response control, steady state error, second-order system performance, effect of the third pole and zero on the second-order system response, control system performance index, simplification of the linear system, stability analysis of open loop and closed loop systems, system stability test using the characteristic function method and the Ruth Hurwitz method; Control System Design: root locus concept, control parameter design using the root locus method , Determination of PID parameters using trial and error method, process identification for stable open loop system, determination of PID parameters using the methods: Direct Synthesis, Inter Model Control, system performance index, Ziegler Nichols, Cohen Coon and Reaction curves; analysis of system frequency response performance using Bode and Nyquist plot, Pi control system design, PID, Lead, lag and Lead Lag, feedback system design with state variable. Digital Control System

References:

1. Dorf, Richard C., and Bishop, Robert H., *Modern Control System*, Prentice Hall, 2011

2. Golnaraghi, Farid., and Kuo, Benjamin C., *Automatic Control System*, John Wiley & Son., 2010.

3. Seborg, Dale E., Edgar, Thomas F., and Mellichamp, Duncan A., *Process Dynamics and Control*, John Wiley & Son., 2004.

23. Control System Laboratory Work

Code/Credit/Prerequisite: SCPH603715/1 Credit/Electronics 2

Course Learning Outcome:

Apply control system principles for process identification and simple continuous linear system design of a process that has fast and slow response to time.

Topics:

Introduction to control systems and programming in Matlab and LabVIEW languages, system representation with transfer functions, state variables including system linearization techniques, system response to various standard signals, and control techniques, determination of PID parameters using methods 1. Trial and Error, 2. Direct Synthesis, 3. Zieler Nichols reaction curve. Its applications are to DC motor control systems, inverted pendulum control, HVAC (heating, ventilation and air conditioning).

References:

1. Dorf, Richard C., and Bishop, Robert H., *Modern Control System*, Prentice Hall, 2011
2. Golnaraghi, Farid., and Kuo, Benjamin C., *Automatic Control System*, John Wiley & Son., 2010.
3. Seborg, Dale E., Edgar, Thomas F., and Mellichamp, Duncan A., *Process Dynamics and Control*, John Wiley & Son., 2004.
4. Quanser, *QNET DC Motor Trainer, QNET Rotary Pendulum Trainer, QNET Heating and Ventilation Trainer*, 2009

24. Digital Signal Processing

Code/Credit/Prerequisite: SCPH604708/2 credits/Modern Physics, Mathematical Methods in Physics 2, Electronics 2

Course Learning Outcome:

Explain digital processing systems and able to perform signal processing in the discrete time domain and discrete frequency, as well as apply them for digital filter applications.

Topics:

System signal recognition, analog to digital signal conversion and vice versa, discrete time signal, Z transform and its application to time-invariant linear (LTI) system, continuous time signal frequency analysis, discrete time signal frequency analysis, Fourier transform for discrete time signals, concepts filter, digital filter FIR, IIR.

References:

1. Kehtarnavas, N., *Digital Signal Processing System Design: LabVIEW-Based Hybrid Programming*, Academic Press, 2008.
2. Ingle, V.K., and Proakis, J.G., *Digital Signal Processing using Matlab*, Cengage Learning, 4th Ed., 2012.
3. Oppenheim, A.V. and Schafer, R.W., *Discrete-Time Signal Processing (3rd Ed)*, Prentice Hall, 2009.

25. Artificial intelligence

Code/Credit/Prerequisite: SCPH604707/2 credits/Calculus 1&2, Elementary Linear Algebra, Computational Physics.

Course Learning Outcome:

Describe the basic concepts of artificial intelligence and apply them to analyze and design an intelligent system.

Topics:

introduction to artificial intelligence; problem representation & heuristic search techniques: hill climbing, simulated annealing, depth, breadth, best first search, genetic algorithm and A-star algorithm; knowledge representation; reasoning: rule-based, fuzzy logic, diagnosis reasoning; machine learning & learning algorithms: supervised learning: regression, support vector machine, artificial neural networks, unsupervised learning: partitional-based clustering, hierarchical clustering, self-organizing maps; reinforcement learning; statistical learning; deep learning.

References:

1. S.J.Russel and P.Norvig, *Artificial Intelligence: A Modern Approach*, 3rd edition, Pearson, 2016.
2. V.Chandra and A.Hareendran, *Artificial Intelligence and Machine Learning*, PHI Learning, 2014.
3. G.James, D.Witten, T.Hastie and R.Tibshirani, *An Introduction to Statistical Learning*, Springer, 2017.
4. E.Alpaydin, *Introduction to Machine Learning*, 4th edition, MIT Press, 2020

26. Data Acquisition System

Code/Credit/Prerequisite: SCPH604709/2 credits/Electronics 2

Course Learning Outcome:

Explain the various basic techniques for data acquisition using computer using LabVIEW software or programming language.

Topics:

Introduction to computer-based data acquisition systems, introduction to graphic programming with LabVIEW, Input - Output in computer systems, signal conditioning techniques, Analog to Digital Converter (ADC) and Digital to Analog Converter (DAC), serial and parallel data communication systems, simple examples of acquisition technique designs

References:

1. Cotfas, P.A., Cotfas, D.T., Ursutiu, D. and Samoila, C., *NI ELVIS Computer-Based Instrumentation*, NTS, 2012

2. Travis, J., and Kring, J. LabVIEW for Everyone, 3rd Ed., Prentice Hall, 2006

3. Sumathi, S. and Surekha, P., *LabVIEW based Advanced Instrumentation Systems*, Springer, 2007.

27. Instrumentation System

Code/Credit/Prerequisite: SCPH604710/2 credits/Electronics 2

Course Learning Outcome:

Describe the basic principles of the Instrumentation system.

Topics:

Types of instrumentation. Instrumentation system modeling. RLC Meter, Lock-In Amplifier, Impedance meter, Bioimpedance Analyzer, Spectrum Analyzer, Vector Network Analyzer

References:

1. Boyes, Walt, *Instrumentation Reference Book, 3rd Ed,* Butterworth – Heinemann, 2003.
2. Webster, John G., *Measurement Instrumentation and Sensor Handbook,* CRC Press, 1999.

28. Introduction to Radiological Physics and Dosimetry

Code/Credit/Prerequisite: SCPH603716/2 credits/Modern Physics

Course Learning Outcome:

describe the basic principles and concepts of radiological physics and dosimetry.

Topics:

Radiation classification, radiation quantities and units, direct and indirect ionizing radiation, interaction of radiation with matter, exponential attenuation, radioactive decay, charged particles and radiation balance, radiation dosimetry, cavity theory, ionization chambers, calibration of photons and electrons with ionization chambers, relative dosimetry techniques, and absolute dosimetry techniques

References:

1. F. H. Attix. *Introduction of Radiological Physics and Radiation Dosimetry*, John Willey and Sons, New York, NY, 1986.
2. H. E. Johns and J. R. Cunningham. *The Physics of Radiology*, 4th ed., Charles C. Thomas, Springfield, IL, 1983.
3. J. F. Knoll. *Radiation Detection and Measurement*. 3rd. ed., John Willey and Sons, New York, NY, 2000.
4. Podgorsak, *Radiation Oncology Physics: Handbook for Teacher and Student*, IAEA, 2005.
5. Metcalfe, *et al*, *The Physics of Radiotherapy X-rays and Electron,* Medical Physics Publishing, 2007.

29. Anatomy and Physiology

Code/Credit/Prerequisite: SCPH603717/2 credits/General Biology

Course Learning Outcome:

State medical terminology, roughly identify anatomical structures, define most organ systems, and describe physiological mechanisms for repair, maintenance and growth.

Topics:

Nomenclature of anatomy, bones, spinal column, thorax, abdomen, respiratory system, digestive system, urinary system, reproductive system, circulatory system, and pathology

References:

1. R. Putz and R. Pabst, *Sobotta Atlas of Human Anatomy,* EGC, 2010.
2. Serwood, *Human Physiology: from cell to system,* EGC, 2001

30. Introduction to Biomaterials

Code/Credit/Prerequisite: SCPH604711/2 credits/Introduction to Solid State Physics

Course Learning Outcome:

explain the concept of biomaterials and their applications

Topics:

Introduction to materials, Ceramics, Metals, Polymers, Composition and structure of hard tissue mineral components, Synthesis of biomimetic materials, Microstructure of materials, Effects of simple and complex ions in HAP, Tri Calcium Phosphate Materials, Biocomposites, Bioactive glasses and glass ceramics, Biocompatibility of materials, Clinical use of calcium phosphate

References:

1. Buddy D. Ratner. Biomaterial Science: An Introduction to Material in Medicine, Academic Press, 2012
2. C. Mauli Agrawal. Introduction to Biomaterials: Basic Theory with Engineering Application. Cambridge Press, 2013

31. Introduction to Radiotherapy Physics

Code/Credit/Prerequisite: SCPH604712/2 credits/Introduction to Core Physics

Course Learning Outcome:

Describe the application of external and internal radiation beams produced by therapeutic machine.

Topics:

Introduction to radiation oncology, the basis of radiobiology in radiotherapy, clinical photon beam description; Clinical photon beam: point dose calculation; Clinical photon beam: basic clinical dosimetry; Clinical electron beam, basic physical characteristics in brachytherapy and clinical aspects of brachytherapy

References:

1. AAPM Report No. 46. *Comprehensive QA for Radiation Oncology*, American Institute of Physics, New York, 1994
2. AAPM Report No. 47. *AAPM Code of Practice for Radiotherapy Accelerator*, American Institute of Physics, New York, 1994
3. AAPM Report No. 67. *Protocol for Clinical Reference Dosimetry of High Energy Photon and Electron Beams*, American Institute of Physics, New York, 1999.
4. IAEA Report No. 23. *Absorbed Dose Determination in Photon and Electron Beams. An International Code of Practice*, International Atomic Energy Agency, Vienna, Austria, 1987.

5. ICRU Report No. 38. *Dose and Volume Specifications for Reporting Intracavitary Therapy in Ginecology,* International Commission on Radiation Unit and Measurements, Bethesda, MD, 1985.
6. ICRU Report No. 50. *Prescribing, Recording and Reporting Photon Beam Therapy,* International Commission on Radiation Unit and Measurements, Bethesda, MD, 1993.
7. H. E. Johns and J. R. Cunningham. *The Physics of Radiology*, 4th ed., Charles C. Thomas, Springfield, IL, 1983
8. S. C. Klevenhagen, *Physics and Dosimetry of Therapy Electron Beams*, Medical Physics Publishing, Madison, WI, 1993
9. W. J. Meredith and J. B. Massey. *Fundamental Physics of Radiology*. 3rd ed., J. Wright, Bristol, UK, 1977
10. J. Van Dyk (Editor). *The Modern Technology of Radiation Oncology* (Medical Physics Publishing, Philadelphia, PA, 1999
11. J. R. Williams and D. I. Thwaites. *Radiotherapy Physics in Practice*, Oxford University Press, New York, 1994
12. Siamak Shahabi (Editor). *Blackburn's Introduction to Clinical Radiation Therapy Physics*, Medical Physics Publishing Corporation, Madison, Wisconsin, 1989
13. P. M. K. Leung. *The Physical Basis of Radiotherapy*, the Ontario Cancer Institute incorporating The Princess Margaret Hospital, 1990.
14. G. C. Bentel, C. E. Nelson, and K.T. Noell. *Treatment Planning Dose Calculation in Radiation Oncology*. McGraw Hill, New York, NY, 1989.

32. Introduction to Biophysics

Code/Credit/Prerequisite: SCPH603718/2 credits/General Biology

Course Learning Outcome:

explain the concept of biophysics specifically the physical process in living things and the application of physics in research on living things.

Topics:

Cells, physics in the human body, the application of physical methods in the research of living things

References:

1. John R. Cameron. Physics of the Body, Medical Physics Publishing Corp, 1999
2. Roland Glaser, *Biophysics*, Springer, 2001.
3. V. Pattabhi. Biophysics, Springer, 2002

33. Health Physics and Radiation Protection

Code/Credit/Prerequisite: SCPH603719/2 credits/Introduction to Core Physics

Course Learning Outcome:

describe the knowledge of the relationship between microscopic interactions with cell responses, deterministic and stochastic effects, and radiation detection equipment and radiation protection.

Topics:

Introduction, Shielding : Properties and design, Nuclear counting statistics, radiation monitoring for personnel, internal exposure, environmental dispersion, biological effects, regulations on radiation protection, low and high grade waste disposal, and non-ionizing radiation

References:

1. ICRP No. 60. 1990 *Recommendations of International Commission on Radiological Protection*, Elsevier Science, 1990.
2. Herman Cember, *Introduction to Health Physics*. 2nd ed., Pergamon Press Inc. New York, NY. 1983.
3. RL. Kathren, *Radiation Protection*, Adam Hilger LTD., Bristol, 1985.
4. D. A. Gollnick. Basic Radiation Protection Technology. 2nd ed., Pacific Radiation Corporation, Altadena, CA, 1993.

34. Radiobiology

Code/Credit/Prerequisite: SCPH603720/2 credits/ Anatomy and physiology

Course Learning Outcome:

Describe the effects of radiation on living cells occurring in all medical activities utilizing ionizing radiation, in the fields of diagnostics, radiotherapy and nuclear medicine

Topics:

Review of radiation interactions with matter, radiation injury to DNA, repair of DNA damage, radiation induced chromosome damage and repair, survival curve theory, cell death: the concept of cell death (apoptosis and cell death reproduction), cellular healing processes, cell cycles, response modifiers of radiation-sensitizer and protector, RBE, OER, and LET, cell kinetics, radiation injury to tissue, radiation pathology - acute and advanced effects, histopathology, tumor radiobiology, TDF (time, dose, and fractionation), radiation genetics: effects of radiation on fertility and mutagenesis, and molecular mechanisms

References:

1. G. Gordon Steel (Editor). *Basic Clinical Radiobiology*, Edward Arnold, London, UK, 1993.
2. Eric J. Hall. *Radiobiology for the Radiologist*. 5th ed., Lippincott Williams and Wilkins, Philadelphia, PA, 2000.

35. Health Physics and Counting System Laboratory Work

Code/Credit/Prerequisite: SCPH604781/1 Credit/Introduction to Core Physics

Course Learning Outcome:

perform scintillation measurement experiments, nuclear spectroscopy, use of diode detectors, TLD, etc.

Topics:

Design of X-ray machine room shielding, characterization of various shielding materials against X-ray energy, calibration of Nuclear Spectroscopy MCA, individual dose monitoring readings of film badges, calibration of survey meter, Nuclear spectroscopy Single Channel Analyzer (SCA), characterization of Geiger Mueller detector work, determination of radionuclide types and TLD dose readings.

Introduction to Nuclear Medicine, Basic Physics in NM 1, Basic Physics in NM 2, Types of detectors in NM, Introduction to instrumentation in NM 1, Introduction to instrumentation in NM 2, Introduction to Radionuclide production 1, Introduction to radionuclide production 2, Introduction to system diagnostic evaluation 1 , Introduction to system diagnostic evaluation 2, Basic concepts of pharmacokinetics in NM 1, Basic concepts of pharmacokinetics in NM 2, Basic concepts of internal dosimetry 1, Basic concepts of internal dosimetry 2, Basic concepts of radiation protection in NM.

References:

1. ICRP No. 60. 1990 *Recommendations of International Commission on Radiological Protection*, Elsevier Science, 1990

2. Herman Cember, *Introduction to Health Physics*. 2nd ed., Pergamon Press Inc. New York, NY. 1983.

3. RL. Kathren, *Radiation Protection*, Adam Hilger LTD., Bristol, 1985.

4. D. A. Gollnick. *Basic Radiation Protection Technology*. 2nd ed., Pacific Radiation Corporation, Altadena, CA, 1993.

36. Introduction to Nuclear Medicine and Medical Imaging Physics

Code/Credit/Prerequisite: SCPH604713/3 credits/Introduction to Core Physics

Course Learning Outcome:

Explain the basic principles of radiography, mammography, dental radiography, computed tomography, ultrasound, magnetic resonance (MRI) and nuclear medicine.

Topics:

image and contrast formation, radiographic receptors, film-screen radiography and fluoroscopy, digital radiography and fluoroscopy, mammography, and dental radiology, CT image formation, CT image quality, the physical principles of Magnetic Resonance Imaging, MRI image formation, the physical principles of Ultrasonography, Ultrasonography image formation, the working principle of Gamma camera, radiopharmaceutical and pharmacokinetics, Internal dosimetry, SPECT-CT, PET and cyclotron, and QA of nuclear medical equipment

References:

1. J. T. Bushberg, J. A. Seibert, E. M. Leidhodt, Jr., J. M. Boone. *The Essential Physics of Medical Imaging*. 2nd ed., Williams and Wilkins, Baltimore, MD, 2002.
2. P.P Dendy and B. Heaton. *Physics of Diagnostic Radiology*, Institute of Physics Publishing, London, UK, 1999.
3. P. Sprawl. *Physical Principles of Medical Imaging*, Aspen Publishers,. Gaithersburg, Maryland, 1987.
4. Adrienne Finch (Editor). *Assurance of Quality in the Diagnostic Imaging Department*, the British Institute of Radiology, London, 2001
5. G. ter Haar and F. A. Duck (Editor). *The Safe Use of Ultrasound in Medical Diagnostic*, the British Institute of Radiology, London, 2001.
6. AAPM Report No. 39. *Specification and Acceptance Testing of Computed Tomography Scanners*, American Institute of Physics, New York, 1993.
7. AAPM Report no. 76. *Quality Control in Diagnostic Radiology*, American Institute of Physics, New York, 2002.
7. Physics in Nuclear Medicine. SR Cherry, JA Sorenson, ME Phelps. 4th ed. Philadelphia, Pennsylvania: Saunders/ Elsevier 2012.
8. Medical Imaging Physics. W.R. Hendee, E.R. Ritenour. 4th ed. New York: Wiley-Liss Inc. 2002.

37. Laboratory Research Project (Special Course)

Code/Credit/Prerequisite: SCPH604714/3 credits/Have completed 64 credits

Course Learning Outcome:

apply theoretical/computational and/or experimental skills in a small research project to a topic from the field of physics and its applications.

Topics:

Performing analytical or numerical calculations in physics and applied physics. Designing research methods, conducting experiments in research laboratory, characterizing experimental results, explaining research results based on physics and applied physics concepts.

References:

Scientific journals/books in the scope of physics and applied physics that support and match research topics

1.2 External Students

1. Basic Physics

Code/Credit/Prerequisite: SCPH601110/2 credits/-

Course Learning Outcome:

explain the basic concepts of physics and their application in everyday life, including mechanics, thermodynamics, electromagnetics, waves & optics

Topics:
laws of motion, translational and rotational motion, law of conservation of mechanical energy, momentum, energy, static and dynamic fluids, heat, expansion, heat transfer, thermodynamics, heat engines, mechanical vibrations, sound, electricity, electric charge, electric current, magnetism, electromagnetic waves, light, optics, modern physics, atoms

References:

1. Ostdiek, *Inquiry into Physics 7th Edition*, John Wiley & Sons, Inc., 2013.
2. Cutnell and Johnson, *Physics 9th*, Wiley, 2012
3. E. R. Huggins, *Physics 2000*, Moose Mountain Digital Press 2000.

2. Minor Courses in the Undergraduate Program in Physics.

Table 4.8 Minor Courses in the Undergraduate Program in Physics

No	Semester	Code	Course Name	Credit	Status
Semester 1					
1	1	SCPH601101	Basic Physics 1	4	MKP
2	1	SCMA601120	Elementary Linear Algebra	2	MKP
3	1	SCMA601001	Calculus 1	3	MKP
			Total Credits for Semester 1	**9**	
Semester 2					
1	2	SCPH601201	Basic Physics 2	4	MKP
2	2	SCPH601213	Mathematical Methods in Physics 1	3	MKP
3	2	SCMA601002	Calculus 2	3	MKP
			Total Credits for Semester 2	**10**	
Semester 3					
1	3	SCPH602111	Mathematical Methods in Physics 2	4	MKP
2	3	SCPH602133	Modern Physics	3	MKP
3	3	SCPH602135	Thermodynamics	3	MKP
			Total Credits for Semester 3	**10**	
Semester 4					
1	4	SCPH602221	Electromagnetic Field 1	3	MKP
2	4	SCPH602223	Classical Mechanics	4	MKP
3	4	SCPH602222	Quantum Physics 1	4	MKP
4	4	SCPH602214	Computational Physics	4	MKP
5	4	SCPH602235	Vibrations & Waves	3	MKP
			Total Credits for Semester 4	**18**	
			Grand Total	**47**	

TRANSITION RULES

Curriculum 2020 applies to the 2020 generation students. The compulsory courses in the previous curriculum, namely the 2016 Curriculum, are still provided by the Study Program until students complete their study. However, if there are courses in the 2020 Curriculum that have the same contents as the courses in the 2016 Curriculum, students can take the courses in the 2020 Curriculum.