TEACHING INSTRUCTIONAL DESIGN (BRP)

COURSE

NUCLEAR AND PARTICLE PHYSICS

by

Prof. Dr. Anto Sulaksono and Dr. Agus Salam

Undergraduate Program in Physics
Faculty of Mathematics and Natural Sciences
Universitas Indonesia
Depok
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UNIVERSITAS INDONESIA
FACULTY OF MATHEMATICS AND NATURAL SCIENCES
PHYSICS UNDERGRADUATE STUDY PROGRAM

TEACHING INSTRUCTIONAL DESIGN

Course Name	Nuclear and Particle Physics	**Credit(s)**	**Prerequisite course(s)**	**Requisite for course(s)**	**Integration Between Other Courses**
Course Code	SCPH604701	4	Quantum Physics 1, Introduction to Nuclear Physics	-	-
Relation to Curriculum	Elective Course				
Semester	6				
Lecturer(s)	1. Prof. Dr. Anto Sulaksono 2. Dr. Agus Salam				
Course Description	The Nuclear and Particle Physics course is an elective course with course materials being explored to a greater extent than in the Introduction to Nuclear Physics course. The purpose of this course is to give a sufficient foundation before students begin their research. Course materials on nuclear physics include electromagnetic transition rates, the collective nuclear model, and the microscopic nuclear model, whereas course materials on particle physics include relativistic kinematics, rotational transformation, parity, charge conjugation, time reversal, bound states of a system with two particles, electromagnetic interactions, the strong interaction, the weak interaction, Feynman’s rule and diagram, particle scattering and decay, and spontaneous symmetry breaking.				

Program Learning Outcome (PLO)	
PLO-N (Nuclear Physics)	Understand the phenomena and fundamental concepts in problems within nuclear physics
PLO-P (Particle Physics)	Understand the phenomena and fundamental concepts in problems within particle physics
Course Learning Outcome (CLO)	
CLO-N (Nuclear Physics)	Students can apply three of the most essential concepts in low energy nuclear physics such as electromagnetic transition rates, the collective nuclear model, and the microscopic nuclear model correctly in problems that might arise related to their undergraduate thesis (C3).
CLO-P (Particle Physics)	Students can apply relativistic concepts on the kinematics of a particle reaction, rotation transformations, isospin, parity, charge conjugation, and time reversal in particle reactions; can explain the bound state spectrum of a system of particles; apply Feynman's rule and diagram in particle scattering and decay; explain the origin of particle mass well in problems that might arise related to their undergraduate thesis (C3).
Sub-CLO(s)	
Sub-CLO N1 (Nuclear Physics)	Apply the concept of electromagnetic transition rates. (C3)
Sub-CLO N2 (Nuclear Physics)	Apply the concept of the collective model in low-energy nuclear physics. (C3)
Sub-CLO N3 (Nuclear Physics)	Apply the concept of the microscopic model in low-energy nuclear physics. (C3)
Sub-CLO P1 (Particle Physics)	Apply relativistic concepts to the kinematics of a particle reaction. (C3)
Sub-CLO P2 (Particle Physics)	Apply rotational transformations, isospin, parity, charge conjugation, and time-reversal on particle reactions. (C3)
Sub-CLO P3 (Particle Physics)	Explain the bound state spectrum of a system of particles. (C3)
Sub-CLO P4 (Particle Physics)	Apply Feynman's rule and diagram on particle scattering and decay. (C3)
Sub-CLO P5 (Particle Physics)	Explain the origins of particle mass. (C3)
Study Materials (Nuclear Physics)	Quantization of electromagnetic fields, coupling of radiation and matter, surface deformation, vibration, and nuclear rotation, the vibrational and rotational quantum model (collective model)

	of a nucleus, nucleon-nucleon interaction, phenomenological model of a single particle, the Hartree-Fock approximation (microscopic model).
Study Materials (Particle Physics)	Lorentz transformation, Lorentz invariance, 4-vector momentum and position, collision of two particles, the laboratory frame and the center of mass frame, symmetry and the conservation law, group theory, spin, isospin, parity, charge conjugation, time reversal, the CPT theorem, Schrödinger's equation, the Hydrogen atom, Lamb shift, fine structure, positronium, quarkonium, light mesons, baryons, scattering cross-section, decay rate, the Klein-Gordon equation, the Dirac equation, Maxwell's equation, electron-electron interactions, electron-quark interactions, parton model, Bjorken scaling, quark-quark interaction, asymptotic freedom, weak interaction of leptons, weak interaction of quarks, muon, pion and neutron decay, electroweak unification, the Yang-Mills theory, spontaneous symmetry breaking, Higgs mechanism.
Reading List	1. [Greiner] W. Greiner and J. A. Maruhn, Nuclear Models, Springer, 1989 2. [Griffiths] David Griffiths, Introduction to Elementary Particles, John Wiley & Sons, 1987.

I. Teaching Plan

Week	Sub-CLO	Study Materials [with reference]	Teaching Method [with est. time]	Learning Experiences (*O-E-F)	Sub-CLO Achievement Indicator		Sub-CLO Weight on Course (%)
					General	Specific	
1	Sub-CLO N1	Quantization of electromagnetic fields **[Greiner, Chapter 5]**	Interactive lecture, Independent study **[150 minutes]**	**Orientation:** Students see files, videos or use chatrooms in EMAS (30%) **Exercise:** Students discuss via MS Teams or chatrooms in EMAS (30%) Students find reading material to better understand the discussion topic (30%) **Feedback:** Lecturer responds to discussions in MS Teams or chatrooms in EMAS (10%)	Students can apply the concept of quantization for electromagnetic fields	Students can calculate the transition probability for interactions between an electromagnetic field and a particle	5%
2	Sub-CLO N1	Coupling of radiation and matter **[Greiner, Chapter 5]**	Interactive lecture, Independent study **[150 minutes]**	**Orientation:**	Students can apply the concept of coupling between	Students can calculate the transition rate of the	10%

				Students see files, videos or use chatrooms in EMAS (30%) **Exercise:** Students discuss via MS Teams or chatrooms in EMAS (30%) Students find reading material to better understand the discussion topic (30%) **Feedback:** Lecturer responds to discussions in MS Teams or chatrooms in EMAS (10%)	radiation and matter for cases where the matter is a nucleon	interaction between an electromagnetic field and a nucleon	
3	Sub-CLO N2	Surface deformation, vibration, and nuclear rotation **[Greiner, Chapter 6]**	Interactive lecture, Independent study **[150 minutes]**	**Orientation:** Students see files, videos or use chatrooms in EMAS (30%) **Exercise:** Students discuss via MS Teams or	Students can explain the concept of surface deformation and its implications such as vibration and rotation.	Students can calculate kinetic and potential energy classically for charged droplets with vibration and rotation.	10%

				chatrooms in EMAS (30%) Students find reading material to better understand the discussion topic (30%) **Feedback:** Lecturer responds to discussions in MS Teams or chatrooms in EMAS (10%)			
4	Sub-CLO N2	The vibrational and rotational quantum model (collective model) of a nucleus **[Greiner, Chapter 6]**	Interactive lecture, Independent study **[150 minutes]**	**Orientation:** Students see files, videos or use chatrooms in EMAS (30%) **Exercise:** Students discuss via MS Teams or chatrooms in EMAS (30%) Students find reading material to better understand the discussion topic (30%) **Feedback:**	Students can apply the concept of quantization for charged droplet Hamiltonians with vibration and rotation	Students can calculate the vibrational and rotational spectrum of a nucleon	5%

				Lecturer responds to discussions in MS Teams or chatrooms in EMAS (10%)			
5	Sub-CLO N3	Nucleon-nucleon interaction **[Greiner, Chapter 7]**	Interactive lecture, Independent study **[150 minutes]**	**Orientation:** Students see files, videos or use chatrooms in EMAS (30%) **Exercise:** Students discuss via MS Teams or chatrooms in EMAS (30%) Students find reading material to better understand the discussion topic (30%) **Feedback:** Lecturer responds to discussions in MS Teams or chatrooms in EMAS (10%)	Students can explain important concepts on nucleon-nucleon interaction, such as its short-range, spin dependence, isospin, and tensors.	Students can show the potential shapes from nucleon-nucleon interactions.	5%
6	Sub-CLO N3	Phenomenological model of a single particle **[Greiner, Chapter 7]**	Interactive lecture, Independent study **[150 minutes]**	**Orientation:** Students see files, videos or use chatrooms in EMAS (30%)	Students can explain the single particle model, its strengths, and weaknesses	Students can explain magic numbers based on this model	5%

				Exercise: Students discuss via MS Teams or chatrooms in EMAS (30%) Students find reading material to better understand the discussion topic (30%) **Feedback:** Lecturer responds to discussions in MS Teams or chatrooms in EMAS (10%)			
7	Sub-CLO N3	The Hartree-Fock approximation (microscopic model) **[Greiner, Chapter 7]**	Interactive lecture, Independent study **[150 minutes]**	**Orientation:** Students see files, videos or use chatrooms in EMAS (30%) **Exercise:** Students discuss via MS Teams or chatrooms in EMAS (30%) Students find reading material to better understand the	Students can apply approximation concepts in many-body problems to generate the Hartree-Fock equation	Students can calculate the binding energy of a nucleus using the Skyrme-Hartree-Fock model the relativistic mean-field	10%

				discussion topic (30%) **Feedback:** Lecturer responds to discussions in MS Teams or chatrooms in EMAS (10%)			
8	**Midterm Exam**						
9	Sub-CLO P1: Apply relativistic concepts to the kinematics of a particle reaction.	Lorentz transformation, Lorentz invariance, 4-vector momentum and position, collision of two particles, the laboratory frame and the center of mass frame **[Griffiths, Chapter 3]**	Interactive lecture, Independent study **[150 minutes]**	**Orientation:** Students see files, videos or use chatrooms in EMAS (30%) **Exercise:** Students discuss via MS Teams (30%) Students find reading material to better understand the discussion topic (30%) **Feedback:** Lecturer responds to discussions in MS Teams (10%)	Students can apply the concept of Lorentz invariance to the kinematics of a particle reaction	Students can calculate the kinematic magnitudes of a collision between two particles in the laboratory and center of mass frame	10%
10	Sub-CLO P2: Apply rotational transformations, isospin, parity,	Symmetry and the conservation law, group theory, spin, isospin, parity, charge	Interactive lecture, Independent study **[150 minutes]**	**Orientation:** Students see files, videos or use	Students can apply the angular momentum, isospin, parity, and	Students can calculate final magnitudes from the	10%

	charge conjugation, and time-reversal on particle reactions.	conjugation, time reversal, the CPT theorem **[Griffiths, Chapter 4]**		chatrooms in EMAS (30%) **Exercise:** Students discuss via MS Teams (30%) Students find reading material to better understand the discussion topic (30%) **Feedback:** Lecturer responds to discussions in MS Teams (10%)	charge conservation laws in particle reaction equations	initial state of a particle reaction	
11	Sub-CLO P3: Explain the bound state spectrum of a system of particles.	Schrödinger's equation, the Hydrogen atom, Lamb shift, fine structure, positronium, quarkonium, light mesons, baryons **[Griffiths, Chapter 5]**	Interactive lecture, Independent study **[150 minutes]**	**Orientation:** Students see files, videos or use chatrooms in EMAS (30%) **Exercise:** Students discuss via MS Teams (30%) Students find reading material to better understand the discussion topic (30%)	Students can explain the energy spectrum of positronium and quarkonium	Students can calculate the energy spectrum of positronium and quarkonium	5%

				Feedback: Lecturer responds to discussions in MS Teams (10%)			
12	Sub-CLO P4: Apply Feynman's rule and diagram on particle scattering and decay.	Scattering cross-section, decay rate, the Klein-Gordon equation, the Dirac equation, Maxwell's equation, electron-electron interactions **[Griffiths, Chapter 6 and 7]**	Interactive lecture, Independent study **[150 minutes]**	**Orientation:** Students see files, videos or use chatrooms in EMAS (30%) **Exercise:** Students discuss via MS Teams (30%) Students find reading material to better understand the discussion topic (30%) **Feedback:** Lecturer responds to discussions in MS Teams (10%)	Students can apply Feynman's rule and diagram on particle reactions	Students can calculate the transition amplitude of electron-electron scattering	10%
13	Sub-CLO P4: Apply Feynman's rule and diagram on particle scattering and decay.	Electron-quark interactions, parton model, Bjorken scaling, quark-quark interaction, asymptotic freedom **[Griffiths, Chapter 8 and 9]**	Interactive lecture, Independent study **[150 minutes]**	**Orientation:** Students see files, videos or use chatrooms in EMAS (30%) **Exercise:**	Students can apply Feynman's rule and diagram on particle reactions	Students can calculate the transition amplitude of electron-quark interactions and quark-quark interactions	5%

				Students discuss via MS Teams (30%) Students find reading material to better understand the discussion topic (30%) **Feedback:** Lecturer responds to discussions in MS Teams (10%)			
14	Sub-CLO P4: Apply Feynman's rule and diagram on particle scattering and decay.	Weak interaction of leptons, weak interaction of quarks, muon, pion, and neutron decay, electroweak unification **[Griffiths, Chapter 10]**	Interactive lecture, Independent study **[150 minutes]**	**Orientation:** Students see files, videos or use chatrooms in EMAS (30%) **Exercise:** Students discuss via MS Teams (30%) Students find reading material to better understand the discussion topic (30%) **Feedback:** Lecturer responds to discussions in MS Teams (10%)	Students can apply Feynman's rule and diagram on particle reactions	Students can calculate the transition amplitude of muon, pion, and neutron decay	5%

15	Sub-CLO P5: Explain the origins of particle mass	The Yang-Mills theory, spontaneous symmetry breaking, Higgs mechanism **[Griffiths, Chapter 11]**	Interactive lecture, Independent study **[150 minutes]**	**Orientation:** Students see files, videos or use chatrooms in EMAS (30%) **Exercise:** Students discuss via MS Teams (30%) Students find reading material to better understand the discussion topic (30%) **Feedback:** Lecturer responds to discussions in MS Teams (10%)	Students can explain the origins of particle mass	Students can apply the Higgs mechanism on particle equations of motion	5%
16	**Final Exam**						

II. Assignment Design

Week	Assignment Name	Sub-CLOs	Assignment	Scope	Working Procedure	Deadline	Outcome
1-2	Individual Assignment N1	Sub-CLO N1	Making a paper	Electromagnetic radiation transition in the nucleus	Group assignment discussed via EMAS chatroom and finished online	End of midterm	Paper uploaded to EMAS
3-4	Individual Assignment N2	Sub-CLO N2	Making a paper	The collective model	Group assignment discussed via EMAS chatroom and finished online	End of midterm	Paper uploaded to EMAS
5-7	Individual Assignment N3	Sub-CLO N3	Making a paper	The microscopic model	Group assignment discussed via EMAS chatroom and finished online	End of midterm	Paper uploaded to EMAS
8	Midterm Exam	Sub-CLO N1, N2, N3	Problem set	Electromagnetic radiation transition in the nucleus, the collective model, and the microscopic model	Online exam via EMAS	100 minutes	Answer uploaded to EMAS
9	Individual Assignment P1	Sub-CLO P1	Problem set	Collision of two particles	Homework	1 week	Answer uploaded to EMAS
10	Quiz P1	Sub-CLO P2	Problem set	The concept of isospin, parity, charge conjugation, and time reversal	Assignment in EMAS	30 minutes	Questions answered in EMAS
11	Quiz P2	Sub-CLO P3	Problem set	Schrödinger’s equation, separation of variables	Assignment in EMAS	30 minutes	Questions answered in EMAS

12	Individual Assignment P2	Sub-CLO P4	Problem set	Transition amplitude of electron-electron scattering	Homework	1 week	Answer uploaded to EMAS
13	Individual Assignment P3	Sub-CLO P4	Problem set	Transition amplitude of quark-quark scattering	Homework	1 week	Answer uploaded to EMAS
14	Individual Assignment P4	Sub-CLO P4	Problem set	Transition amplitude of muon decay	Homework	1 week	Answer uploaded to EMAS
15	Quiz P3	Sub-CLO P5	Problem set	Klein-Gordon, Dirac, Maxwell, and Proca Lagrangian	Assignment in EMAS	30 minutes	Questions answered in EMAS
16	Final Exam	Sub-CLO P1, P2, P4	Problem set	Collision of two particles, isospin, transition amplitude of pion decay	Online exam via EMAS	100 minutes	Questions answered in EMAS

III. Assessment Criteria (Learning Outcome Evaluation)

Evaluation Type	Sub-CLO	Assessment Type	Frequency	Evaluation Weight (%)
Individual Assignment	N1, N2, N3	EMAS Worksheet	3	20
Individual Assignment	P1, P4	EMAS Worksheet	4	10
Quiz	P2, P3, P5	Quiz via EMAS	3	10
Midterm Exam	N1, N2, N3	Online Exam via EMAS	1	30
Final Exam	P1, P2, P4	Online Exam via EMAS	1	30
			Total:	**100**

IV. Rubric(s)

This rubric is used as a guideline for assessing or giving levels of student performance results. a rubric usually consists of assessment criteria that include the dimensions / aspects that are assessed based on indicators of learning achievement. This assessment rubric is useful for clarifying the basics and aspects of the assessment so that students and lecturers can be guided by the same thing regarding the expected performance demands. Lecturers can choose the type of rubric according to the assessment given.

A. Conversion of the student's final score

Score	Grade	Equivalent
85 - 100	A	4.00
80 - < 85	A-	3.70
75 - < 80	B+	3.30
70 - < 75	B	3.00
65 - < 70	B-	2.70
60 - < 65	C+	2.30
55 - < 60	C	2.00
40 - < 50	D	1.00
< 40	E	0.00

B. Assessment rubric: project report and papers

Criteria	Score	Indicator
Introduction	4	Contains: (1) background for the preparation of the report, (2) problem identification / gap analysis, (3) questions (4) objectives, and (5) citing relevant and current references
	3	Loads the goal and 3 of the other 4 items
	2	Loading objective and 2 of the other 4 items
	1	Does not contain the purpose of preparing the report, there are one or more than 4 other items
	0	Does not contain objectives and 4 other items
Content	4	Structured & cohesive, conducts a comprehensive literature review and performs a complete critical analysis

	3	Structured, conduct a comprehensive literature review and complete critical analysis
	2	Less structured, conducting literature reviews but less comprehensive and carrying out simple critical analysis
	1	Unstructured & cohesive, review of literature is not comprehensive and does not contain critical analysis
Conclusion	4	Related to the implementation of tasks and there are suggestions for feasible improvements to the next assignment
	3	It is related to the implementation of tasks and there are suggestions for improvement of the next assignment but it is not feasible
	2	Regarding the implementation of the task but no suggestions
	1	Not related to the execution of duties and no suggestions
	4	The report is neat and attractive, complete with cover and photo / picture
	3	The report is neat and attractive, with a cover or photo / image
	2	The report includes a cover or photo / image but is not neat or attractive
	1	The report is not neat and unattractive, does not have a cover and photo / image
	4	Easy to understand, correct word choice, and spelling all right
	3	Easy to understand, correct word choice, some misspellings
	2	Less understandable, inaccurate word choice, and some misspellings
	1	It is not easy to understand, the choice of words is not quite right, and there are lots of misspellings