TEACHING INSTRUCTIONAL DESIGN (BRP)

COURSE

NUCLEAR AND PARTICLE PHYSICS

by

Dr. Agus Salam

Undergraduate Program in Physics
Faculty of Mathematics and Natural Sciences
Universitas Indonesia
Depok
December 2017

PREFACE

A Teaching Instructional Design, abbreviated BRP, contains lesson plans for one semester. This BRP is designed to be used as an instruction reference for the Nuclear and Particle Physics course in the Universitas Indonesia Faculty of Mathematics and Natural Sciences Department of Physics.

The Nuclear and Particle Physics course is to be enrolled by 5th term physics students who have taken the Nuclear and Particle Physics specialization, on the condition that they have taken the Modern Physics course and the Mathematical Methods in Physics 3 course.

In the Nuclear and Particle Physics course, students will learn nuclear and particle phenomena by applying concepts in both classical and quantum physics. Students will also learn the fundamental principles behind the experiments that were done to study those phenomena. At the end of this course, students will present their allotted assignment given by the lecturer according to the topics of the course.

With the creation of this BRP, it is hoped that this document can be a reference for the learning process, for lecturers and participants in this course in particular, and those interested in the general public in general.

Jakarta, 17 December 2017

Dr. Agus Salam

I. General Information

1.	Name of Program / Study Level	:	Physics / Undergraduate
2.	Course Name	:	Nuclear and Particle Physics
3.	Course Code	:	SCFI603415
4.	Semester	:	5
5.	Credit	:	4 credits
6.	Teaching Method(s)	:	Interactive Lecture
7.	Prerequisite course(s)	:	Quantum Mechanics 1, Introduction to Nuclear Physics
8.	Requisite for course(s)	:	-
9.	Integration Between Other Courses	:	-
10.	Lecturer(s)	:	Dr. Agus Salam
11.	Course Description	:	Nuclear phenomena; nuclear models; nuclear radiation; applications of nuclear physics; energy deposition in a medium; particle detection; accelerators; characteristics and interactions of elementary particles; symmetry; discrete transformations; neutral kaons; oscillations; CP violation; formulation of the standard model; the standard model and experimental data; beyond the standard model.

II. Course Learning Outcome (CLO) and Sub-CLOs

A. CLO

After students finish this course, they will have a greater and wider understanding of nuclear and particle phenomena, both theoretically and experimentally, so that they are prepared to study nuclear and particle physics in greater detail and more quantitatively.

B. Sub-CLO

It is hoped that after the completion of this course students are able to:

1. identify and understand nuclear phenomena,
2. explain nuclear characteristics using nuclear models,
3. explain the mechanism for nuclear radiation by applying concepts in quantum mechanics,
4. explain the applications of nuclear physics in human life,
5. explain the mechanism for energy deposition in a medium by applying concepts in both classical and quantum physics,
6. explain several methods for detecting particles,
7. explain several methods for accelerating particles,
8. explain the characteristics and classification for elementary particles,
9. utilize symmetry in explaining the characteristics and interactions of particles,
10. explain the relation between discreet transformation and the conservation law,
11. explain the neutral kaon phenomena and its relation to the concept of oscillation and CP violation,
12. understand the formulation for the standard model of elementary particles,
13. understand the advantages and disadvantages of the standard model compared to experimental data,
14. understand models beyond the standard model.

III. Teaching Plan

Week	Sub-CLO	Study Materials	Teaching Method	Time Required	Learning Experiences (*O-E-F)	Sub-CLO Weight on Course (%)	Sub-CLO Achievement Indicator	References
1	1	Labeling of Nuclei; Mass of Nuclei; Size of Nuclei; Nuclear Spins and Dipole Moments; Stability of Nuclei; Instability of Nuclei; Nature of the Nuclear Force	Lecturing, Presentation by students	2x50 minutes	70% O, 30% F	6	Students can identify and understand nuclear phenomena	Chapter 2
2	2	The Liquid Drop Model; The Fermi-Gas Model; The Shell Model; Infinite Square Well; Harmonic Oscillator; Spin-Orbit Potential; Predictions of the Shell Model; Collective Model; Superdeformed Nuclei	Lecturing	2x50 minutes	70% O, 30% F	6	Students can explain nuclear characteristics using nuclear models	Chapter 3
3	3	Alpha Decay; Barrier Penetration; Beta Decay; Lepton Number; Neutrino Mass; The Weak Interaction; Gamma Decay	Lecturing	2x50 minutes	70% O, 30% F	6	Students can explain the mechanism for nuclear radiation by applying concepts in quantum mechanics	Chapter 4
4	4	Nuclear Fission; Basic Theory of Fission; Chain Reaction; Nuclear Fusion; Radioactive Decay; Radioactive Equilibrium; Natural Radioactivity and Radioactive Dating	Lecturing	2x50 minutes	70% O, 30% F	6	Students can explain the applications of nuclear physics in human life	Chapter 5
5	5	Charged Particles; Units of Energy Loss and Range; Straggling, Multiple	Lecturing	2x50 minutes	70% O, 30% F	6	Students can explain the mechanism for energy deposition in a	Chapter 6

		Scattering, and Statistical Processes; Energy Loss Through Bremsstrahlung; Interactions of Photons with Matter; Photoelectric Effect; Compton Scattering; Pair Production; Interactions of Neutrons; Interaction of Hadrons at High Energies					medium by applying concepts in both classical and quantum physics	
6	6	Ionization Detectors; Ionization Counters; Proportional Counters; Geiger-Müller Counters; Scintillation Detectors; Time of Flight; Cherenkov Detectors; Semiconductor Detectors; Calorimeters; Layered Detection	Lecturing	2x50 minutes	70% O, 30% F	10	Students can explain several methods for detecting particles	Chapter 7
7	7	Electrostatic Accelerators; Cockcroft-Walton Machines; Van de Graaff Accelerator; Resonance Accelerators; Cyclotron; LINAC or Linear Accelerators; Synchronous Accelerators; Phase Stability; Strong Focusing; Colliding Beams	Lecturing	2x50 minutes	70% O, 30% F	10	Students can explain several methods for accelerating particles	Chapter 8
8	**Midterm Exam**							
9	8	Forces; Elementary Particles; Quantum Numbers; Baryon Number; Lepton Number; Strangeness; Isospin; Gell-	Lecturing	2x50 minutes	70% O, 30% F	10	Students can explain the characteristics and classification for elementary particles	Chapter 9

		Mann-Nishijima Relation; Production and Decay of Resonances; Determining Spins; Violation of Quantum Numbers; Weak Interactions; Hadronic Weak Decays; Semileptonic Processes; Electromagnetic Processes						
10	9	Symmetries in the Lagrangian Formalism; Symmetries in the Hamiltonian Formalism; Infinitesimal Translations; Infinitesimal Rotations; Symmetries in Quantum Mechanics; Continuous Symmetries; Isotopic Spin; Local Symmetries	Lecturing	2x50 minutes	70% O, 30% F	10	Students can utilize symmetry in explaining the characteristics and interactions of particles	Chapter 10
11	10	Parity; Conservation of Parity; Violation of Parity; Time Reversal; Charge Conjugation; CPT Theorem	Lecturing	2x50 minutes	70% O, 30% F	10	Students can explain the relation between discreet transformation and the conservation law	Chapter 11
12	11	Neutral Kaons; CP Eigenstates of Neutral Kaons; Strangeness Oscillation; K10 Regeneration; Violation of CP Invariance; Time Development and Analysis of the K°-K° System; Semileptonic K° Decays	Lecturing	2x50 minutes	30% O, 40% E, 30% F	6	Students can explain the neutral kaon phenomena and its relation to the concept of oscillation and CP violation	Chapter 12
13	12	Quarks and Leptons; Quark Content of Mesons; Quark	Lecturing	2x50 minutes	30% O, 40% E, 30% F	4	Students can understand the	Chapter 13

		Content of Baryons; Need for Color; Quark Model for Mesons; Valence and Sea Quarks in Hadrons; Weak Isospin and Color Symmetry; Gauge Bosons; Dynamics of the Gauge Particles; Symmetry Breaking; Chromodynamics (QCD) and Confinement; Quark-Gluon Plasma					formulation for the standard model of elementary particles	
14	13	Comparisons with Data; Cabibbo Angle and the "GIM" Mechanism; CKM Matrix; Higgs Boson and sin2 6w	Lecturing	2x50 minutes	30% O, 40% E, 30% F	6	Students can understand the advantages and disadvantages of the standard model compared to experimental data	Chapter 14
15	14	Grand Unification; Supersymmetry (SUSY); Gravity, Supergravity, and Superstrings	Lecturing	2x50 minutes	30% O, 40% E, 30% F	4	Students can understand models beyond the standard model	Chapter 15
16	**Final Exam**							

*) O : Orientation
E : Exercise
F : Feedback

References:

1. A. Das and T. Ferbel, *Introduction to Nuclear and Particle Physics*, 2nd ed., World Scientific, 2003.

IV. Assignment Design

Week	Assignment Name	Sub-CLO	Assignment	Scope	Working Procedure	Deadline	Outcome
1	Nuclear Phenomena	1	Group Assignment	Labeling of Nuclei; Mass of Nuclei; Size of Nuclei; Nuclear Spins and Dipole Moments; Stability of Nuclei; Instability of Nuclei; Nature of the Nuclear Force	In-class and online; in groups and independently	2x50 minutes	Student PowerPoint, presentation, and individual
2	Nuclear Models	2	Group Assignment	The Liquid Drop Model; The Fermi-Gas Model; The Shell Model; Infinite Square Well; Harmonic Oscillator; Spin-Orbit Potential; Predictions of the Shell Model; Collective Model; Superdeformed Nuclei	In-class and online; in groups and independently	2x50 minutes	Student PowerPoint, presentation, and individual
3	Nuclear Radiation	3	Group Assignment	Alpha Decay; Barrier Penetration; Beta Decay; Lepton Number; Neutrino Mass; The Weak Interaction; Gamma Decay	In-class and online; in groups and independently	2x50 minutes	Student PowerPoint, presentation, and individual
4	Applications of Nuclear Physics	4	Group Assignment	Nuclear Fission; Basic Theory of Fission; Chain Reaction; Nuclear Fusion; Radioactive Decay; Radioactive Equilibrium; Natural Radioactivity and Radioactive Dating	In-class and online; in groups and independently	2x50 minutes	Student PowerPoint, presentation, and individual
5	Energy Deposition in a Medium	5	Group Assignment	Charged Particles; Units of Energy Loss and Range; Straggling, Multiple Scattering, and Statistical Processes; Energy Loss Through Bremsstrahlung; Interactions of Photons with Matter; Photoelectric Effect; Compton Scattering; Pair Production; Interactions of Neutrons; Interaction of Hadrons at High Energies	In-class and online; in groups and independently	2x50 minutes	Student PowerPoint, presentation, and individual
6	Particle Detection	6	Group Assignment	Ionization Detectors; Ionization Counters; Proportional Counters; Geiger-Müller Counters; Scintillation Detectors; Time of Flight; Cherenkov Detectors; Semiconductor Detectors; Calorimeters; Layered Detection	In-class and online; in groups and independently	2x50 minutes	Student PowerPoint, presentation, and individual

7	Accelerators	7	Group Assignment	Electrostatic Accelerators; Cockcroft-Walton Machines; Van de Graaff Accelerator; Resonance Accelerators; Cyclotron; LINAC or Linear Accelerators; Synchronous Accelerators; Phase Stability; Strong Focusing; Colliding Beams	In-class and online; in groups and independently	2x50 minutes	Student PowerPoint, presentation, and individual
9	Characteristics and Interactions of Elementary Particles	8	Group Assignment	Forces; Elementary Particles; Quantum Numbers; Baryon Number; Lepton Number; Strangeness; Isospin; Gell-Mann-Nishijima Relation; Production and Decay of Resonances; Determining Spins; Violation of Quantum Numbers; Weak Interactions; Hadronic Weak Decays; Semileptonic Processes; Electromagnetic Processes	In-class and online; in groups and independently	2x50 minutes	Student PowerPoint, presentation, and individual
	Symmetry	9	Group Assignment	Symmetries in the Lagrangian Formalism; Symmetries in the Hamiltonian Formalism; Infinitesimal Translations; Infinitesimal Rotations; Symmetries in Quantum Mechanics; Continuous Symmetries; Isotopic Spin; Local Symmetries	In-class and online; in groups and independently	2x50 minutes	Student PowerPoint, presentation, and individual
	Discrete Transformations	10	Group Assignment	Parity; Conservation of Parity; Violation of Parity; Time Reversal; Charge Conjugation; CPT Theorem	In-class and online; in groups and independently	2x50 minutes	Student PowerPoint, presentation, and individual
	Neutral Kaons, Oscillations, and CP Violation	11	Group Assignment	Neutral Kaons; CP Eigenstates of Neutral Kaons; Strangeness Oscillation; K10 Regeneration; Violation of CP Invariance; Time Development and Analysis of the K°-K° System; Semileptonic K° Decays	In-class and online; in groups and independently	2x50 minutes	Student PowerPoint, presentation, and individual
	Formulation of the Standard Model	12	Group Assignment	Quarks and Leptons; Quark Content of Mesons; Quark Content of Baryons; Need for Color; Quark Model for Mesons; Valence and Sea Quarks in Hadrons; Weak Isospin and Color Symmetry; Gauge Bosons; Dynamics of the Gauge Particles; Symmetry Breaking; Chromodynamics (QCD) and Confinement; Quark-Gluon Plasma	In-class and online; in groups and independently	2x50 minutes	Student PowerPoint, presentation, and individual

	The Standard Model and Experimental Data	13	Group Assignment	Comparisons with Data; Cabibbo Angle and the "GIM" Mechanism; CKM Matrix; Higgs Boson and sin2 6w	In-class and online; in groups and independently	2x50 minutes	Student PowerPoint, presentation, and individual
	Beyond the Standard Model	14	Group Assignment	Grand Unification; Supersymmetry (SUSY); Gravity, Supergravity, and Superstrings	In-class and online; in groups and independently		Student PowerPoint, presentation, and individual

V. Assessment Criteria (Learning Outcome Evaluation)

Evaluation Type	Sub-CLO	Assessment Type	Frequency	Evaluation Weight (%)
Individual Assignment	1-4	Answer sheet	0	20
Group Assignment	5-6	Presentation	14	30
Midterm Exam	1-3	Answer sheet	1	30
Final Exam	4-6	Answer sheet	1	40
Total				**100**

VI. Rubric

A. Criteria of Presentation Score

Score	Presentation Delivery
85-90	Group is able to deliver the explanation logically, fluently, and punctual and be able to answer the questions from other students and lecturer
75-84	Group is able to deliver the explanation logically and fluently and be able to answer the questions from other students and lecturer, but be less punctual on delivering the explanation
65-74	Group is able to deliver the explanation fluently, but be less able to deliver the reasoning logic of the explanation
55-64	Group is less able to deliver the explanation fluently and punctual and be less able to deliver the reasoning logic of the explanation
<55	

B. Criteria of Assignment and Exam Scores

Score	Answer Quality
100	Answer is very precise and all the concept and main component are explained completely
76-99	Answer is fairly precise and the concept and main component are explained fairly complete
51-75	Answer is less precise and the concept and main component are explained less complete
26-50	Answer is poorly precise and the concept and main component are explained poorly complete
<25	Answer is wrong