TEACHING INSTRUCTIONAL DESIGN (BRP)

COURSE

RELATIVISTIC QUANTUM MECHANICS

by

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Undergraduate Program in Physics
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<table>
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FACULTY OF MATHEMATICS AND NATURAL SCIENCES
PHYSICS UNDERGRADUATE STUDY PROGRAM</td></tr>
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<tr><td>Course Name</td><td>Relativistic Quantum Mechanics</td><td>Credit(s)</td><td>Prerequisite course(s)</td><td>Requisite for course(s)</td><td>Integration Between Other Courses</td></tr>
<tr><td>Course Code</td><td>SCPH603700</td><td rowspan="4">4</td><td rowspan="4">Quantum Physics 1</td><td rowspan="4">-</td><td rowspan="4">-</td></tr>
<tr><td>Relation to Curriculum</td><td>Elective Course</td></tr>
<tr><td>Semester</td><td>7</td></tr>
<tr><td>Lecturer(s)</td><td>Dr. Agus Salam</td></tr>
<tr><td>Course Description</td><td colspan="5">Outcome: After completing this course, students will be able to apply the concepts and principles in time-dependent electromagnetic fields to solve problems in physics involving electromagnetic interactions.
Scope: String quantization, electromagnetic field quantization, interaction between radiation and matter, the Klein-Gordon equation, the Dirac equation and its applications, second quantization, symmetry, interacting field theory, quantum electrodynamics, renormalization, bound states, and unitarity.
Language of Instruction: Bahasa Indonesia
Teaching Method: Interactive lecture and independent learning</td></tr>
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Program Learning Outcome (PLO)	
PLO-1	Applying classical and modern Physics concepts in general physics problems.
PLO-6.2	Building insight into the latest developments in science and technology related to physics.
Course Learning Outcome (CLO)	
CLO-1	Apply the concepts and formulations in relativistic quantum mechanics to problems within nuclear and particle physics.
Sub-CLO(s)	
Sub-CLO 1	Apply the concept of quantum physics to fields.
Sub-CLO 2	Apply the concept of field quantization to interactions between radiation and matter.
Sub-CLO 3	Explain the Klein-Gordon equation and the Dirac equation.
Sub-CLO 4	Apply the concept of quantum physics to interacting fields.
Sub-CLO 5	Apply quantum electrodynamics and renormalization to particle scattering.
Sub-CLO 6	Apply the concept of field quantization to bound states.
Study Materials	String quantization, electromagnetic field quantization, interaction between radiation and matter, the Klein-Gordon equation, the Dirac equation and its applications, second quantization, symmetry, interacting field theory, quantum electrodynamics, renormalization, bound states, and unitarity.
Reading List	**Required:** [Gross] F. Gross, *Relativistic Quantum Mechanics and Field Theory*, John Wiley & Sons, 1993. **Supplementary:** [Maiani] L. Maiani and O. Benhar, *Relativistic Quantum Mechanics and An Introduction to Relativistic Quantum Field*, Taylor and Francis Group, 2016.

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 1: Apply the concept of quantum physics to fields.	String quantization **[Gross, Chapter 1]**	Interactive lecture, Independent learning **[150 minutes]**	**Orientation:** Students see videos 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 quantum physics to a string	Students can calculate the Hamiltonian of a string	7%
2	Sub-CLO 1: Apply the concept of quantum physics to fields.	Quantization of electromagnetic fields **[Gross, Chapter 2]**	Interactive lecture, Independent learning **[150 minutes]**	**Orientation:** Students see videos in EMAS (30%) **Exercise:** Students discuss via MS Teams (30%) Students find reading material to better understand the	Students can apply quantization to electromagnetic fields	Students can calculate the Hamiltonian of an electromagnetic field	7%

				discussion topic (30%) **Feedback:** Lecturer responds to discussions in MS Teams (10%)			
3	Sub-CLO 2: Apply the concept of field quantization to interactions between radiation and matter.	Time evolution and S-matrix **[Gross, Chapter 3]**	Interactive lecture, Independent learning **[150 minutes]**	**Orientation:** Students see videos 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 perturbation to S-matrices	Students can calculate the transition amplitude of an S-matrix	7%
4	Sub-CLO 2: Apply the concept of field quantization to interactions between radiation and matter.	Lamb shift and deuteron photodisintegration **[Gross, Chapter 3]**	Interactive lecture, Independent learning **[150 minutes]**	**Orientation:** Students see videos in EMAS (30%) **Exercise:** Students discuss via MS Teams (30%)	Students can apply electromagnetic field quantization to atoms	Students can calculate the Lamb shift energy and the deuteron disintegration energy	7%

				Students find reading material to better understand the discussion topic (30%) **Feedback:** Lecturer responds to discussions in MS Teams (10%)			
5	Sub-CLO 3: Explain the Klein-Gordon equation and the Dirac equation.	Klein-Gordon equation **[Gross, Chapter 4]**	Interactive lecture, Independent learning **[150 minutes]**	**Orientation:** Students see videos 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 solution to the Klein-Gordon equation	Students can calculate current from the Klein-Gordon equation	7%
6	Sub-CLO 3: Explain the Klein-Gordon equation and the Dirac equation.	Dirac equation **[Gross, Chapter 5]**	Interactive lecture, Independent learning **[150 minutes]**	**Orientation:** Students see videos in EMAS (30%)	Students can explain the solution to the Dirac equation	Students can calculate current from the Dirac equation	7%

				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%)			
7	Sub-CLO 3: Explain the Klein-Gordon equation and the Dirac equation.	Applications of the Dirac equation **[Gross, Chapter 6]**	Interactive lecture, Independent learning **[150 minutes]**	**Orientation:** Students see videos 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 Dirac equation to cases with spherical potential	Students can calculate the energy spectrum of a system with spherical potential	7%
8	**Midterm Exam**						

9	Sub-CLO 4: Apply the concept of quantum physics to interacting fields.	Second quantization **[Gross, Chapter 7]**	Interactive lecture, Independent learning **[150 minutes]**	**Orientation:** Students see videos 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 solution to the complex Klein-Gordon equation	Students can calculate current from the complex Klein-Gordon equation	7%
10	Sub-CLO 4: Apply the concept of quantum physics to interacting fields.	Symmetry **[Gross, Chapter 8]**	Interactive lecture, Independent learning **[150 minutes]**	**Orientation:** Students see videos in EMAS (30%) **Exercise:** Students discuss via MS Teams (30%) Students find reading material to better understand the discussion topic (30%)	Students can apply Noether's theorem to a symmetry transformation	Students can calculate the conserved magnitudes in CPT	7%

				Feedback: Lecturer responds to discussions in MS Teams (10%)			
11	Sub-CLO 4: Apply the concept of quantum physics to interacting fields.	Interacting Field Theory **[Gross, Chapter 9]**	Interactive lecture, Independent learning **[150 minutes]**	**Orientation:** Students see videos 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 φ^3 field theory for interactions	Students can calculate pion-nucleon interaction	7%
12	Sub-CLO 5: Apply quantum electrodynamics and renormalization to particle scattering.	Quantum Electrodynamics **[Gross, Chapter 10]**	Interactive lecture, Independent learning **[150 minutes]**	**Orientation:** Students see videos in EMAS (30%) **Exercise:** Students discuss via MS Teams (30%) Students find reading material to better understand the	Students can apply electromagnetic interactions to particle scattering	Students can calculate the transition amplitude of an electron-electron scattering process	8%

				discussion topic (30%) **Feedback:** Lecturer responds to discussions in MS Teams (10%)			
13	Sub-CLO 5: Apply quantum electrodynamics and renormalization to particle scattering.	Renormalization **[Gross, Chapter 11]**	Interactive lecture, Independent learning **[150 minutes]**	**Orientation:** Students see videos 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 regularization and loop integrals to electromagnetic interactions	Students can calculate vacuum polarization, self-energy, and radiation correction	8%
14	Sub-CLO 6: Apply the concept of field quantization to bound states.	Bound states **[Gross, Chapter 12]**	Interactive lecture, Independent learning **[150 minutes]**	**Orientation:** Students see videos in EMAS (30%) **Exercise:** Students discuss via MS Teams (30%)	Students can apply the Bethe-Salpeter equation to cases involving bound states	Students can calculate the spectator equation for a system of two particles	7%

				Students find reading material to better understand the discussion topic (30%) **Feedback:** Lecturer responds to discussions in MS Teams (10%)			
15	Sub-CLO 6: Apply the concept of field quantization to bound states.	Unitarity **[Gross, Chapter 12]**	Interactive lecture, Independent learning **[150 minutes]**	**Orientation:** Students see videos 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 Bethe-Salpeter equation to cases involving bound states	Students can calculate the Blankenbecler-Sugar equation for systems with two particles	7%
16	**Final Exam**						

II. Assignment Design

Week	Assignment Name	Sub-CLOs	Assignment	Scope	Working Procedure	Deadline	Outcome
1	Individual Assignment 1	Sub-CLO 1	Problem set	String quantization, electromagnetic field quantization	Homework	1 week	Answer uploaded to EMAS
3	Individual Assignment 2	Sub-CLO 2	Problem set	Interaction between radiation and matter	Homework	1 week	Answer uploaded to EMAS
5	Individual Assignment 3	Sub-CLO 3	Problem set	Klein-Gordon equation, Dirac equation and its applications	Homework	1 week	Answer uploaded to EMAS
8	Midterm Exam	Sub-CLO 1, 2, 3	Problem set	Field quantization, Klein-Gordon quantization, Dirac equation	Online exam via EMAS	100 minutes	Answer uploaded to EMAS
9	Individual Assignment 4	Sub-CLO 4	Problem set	Second quantization, symmetry, interacting field theory	Homework	1 week	Answer uploaded to EMAS
11	Individual Assignment 5	Sub-CLO 5	Problem set	Quantum Electrodynamics, renormalization	Homework	1 week	Answer uploaded to EMAS
13	Individual Assignment 6	Sub-CLO 6	Problem set	Bound states and unitarity	Homework	1 week	Answer uploaded to EMAS
16	Final Exam	Sub-CLO 4, 5, 6	Problem set	Interacting fields, Quantum Electrodynamics, bound states	Online exam via EMAS	100 minutes	Answer uploaded to EMAS

III. Assessment Criteria (Learning Outcome Evaluation)

Evaluation Type	Sub-CLO	Assessment Type	Frequency	Evaluation Weight (%)
Individual Assignment	1, 2, 3, 4, 5, 6	EMAS Worksheet	6	40
Midterm Exam	1, 2, 3	Online Exam via EMAS	1	30
Final Exam	4, 5, 6	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