TEACHING INSTRUCTIONAL DESIGN (BRP)

COURSE

QUANTUM PHYSICS 1

by

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UNIVERSITAS INDONESIA
FACULTY OF MATHEMATICS AND NATURAL SCIENCES
PHYSICS UNDERGRADUATE STUDY PROGRAM

TEACHING INSTRUCTIONAL DESIGN

<table>
<tr><th>Course Name</th><td>Quantum Physics 1</td><th>Credit(s)</th><th>Prerequisite course(s)</th><th>Requisite for course(s)</th><th>Integration Between Other Courses</th></tr>
<tr><th>Course Code</th><td>SCPH602222</td><td rowspan="4">4</td><td rowspan="4">Elementary Linear Algebra, Modern Physics, Mathematical Methods in Physics 2 & 3</td><td rowspan="4">Quantum Physics 2, Relativistic Quantum Mechanics, Scattering Theory, Nuclear and Particle Physics</td><td rowspan="4">None</td></tr>
<tr><th>Relation to Curriculum</th><td>Compulsory Course</td></tr>
<tr><th>Semester</th><td>4th</td></tr>
<tr><th>Lecturer(s)</th><td>Dr. Adam Badra Cahaya</td></tr>
<tr><th>Course Description</th><td colspan="5">The application of fundamental concepts in quantum mechanics, consisting of black body radiation, the photoelectric effect, Compton scattering, wave-particle duality, the Bohr atom, de Broglie waves, the correspondence principle, wave packets, Heisenberg uncertainty principle, Schrödinger’s equation, wave functions, probability interpretation, normalization, expected value, operators, commutative property, stationary state, eigenvalue and eigenfunction, linear operator, hermiticity, expansion theorems, free wave normalization, parity, degeneration, Dirac notation, representation, problems with one-dimensional potential, simple harmonic oscillator and ladder operators, changes in expected value over time, time-dependence of operators, the Schrödinger picture and Heisenberg picture, N-particle systems, central force, Schrödinger’s equation in three dimensions, angular momentum, hydrogen-like atoms in simple quantum systems, and</td></tr>
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	hydrogen-like atoms.
Program Learning Outcome (PLO)	
PLO-1	Apply concepts in classical and modern physics in solving general problems in physics.
PLO-2	Summarize basic knowledge in the field of science and technology.
PLO-3	Apply knowledge of physics in society and practical life, along with identifying and adapting to new discoveries in the field of quantum physics
Course Learning Outcome (CLO)	
CLO-1	After the completion of this course, students will be able to apply fundamental concepts in quantum mechanics to simple quantum systems and atoms such as hydrogen. (C3)
Sub-CLO(s)	
Sub-CLO 1	Able to identify (C1) particle-wave duality in a wave function.
Sub-CLO 2	Able to explain (C2) the concept of the wave function and Schrödinger's equation in the motion of a free particle blocked by a one-dimensional potential.
Sub-CLO 3	Able to explain (C2) the concept of eigenvalue and the wave function of a bounded particle in one dimension.
Sub-CLO 4	Able to apply (C3) the concept of operators in harmonic oscillations, angular momentum, and N-particle systems.
Sub-CLO 5	Able to apply (C3) the concept of wave functions in a hydrogen atom and under a three-dimensional potential.
Study Materials	Black body radiation, the photoelectric effect, Compton scattering, wave-particle duality, the Bohr atom, de Broglie waves, the correspondence principle, wave packets, Heisenberg uncertainty principle, Schrödinger's equation, wave functions, probability interpretation, normalization, expected value, operators, commutative property, stationary state, eigenvalue and eigenfunction, linear operator, hermiticity, expansion theorems, free wave normalization, parity, degeneration, Dirac notation, representation, problems with one-dimensional potential, simple harmonic oscillator and ladder operators, changes in expected value over time, time-dependence of operators, the Schrödinger picture and Heisenberg picture, N-particle systems, central force,

	Schrödinger's equation in three dimensions, angular momentum, hydrogen-like atoms in simple quantum systems, and hydrogen-like atoms.
Reading List	[1] S. Gasiorowicz, *Quantum Physics* 3rd Ed., John Wiley & Sons, Inc., 2003. [2] A. Goswami, *Quantum Mechanics* 2nd Ed., Wm. C. Brown Publishers, 1997.

I. Teaching Plan

Week	Sub-CLO	Study Materials [reference]	Teaching Method [estimated time]	Teaching Mode	Learning Experiences (*O-E-F)		Sub-CLO Achievement Indicator	Sub-CLO Weight on Course (%)
					Online	Offline	General Indicator; Specific Indicator	
1	1	Course contract, introduction to the course. [1] Ch. 1	Interactive lecture, flipped classroom. Discussions via forum and lecture, video conference [100 minutes]	Asynchronous via EMAS UI (independent study and discussion forums) Synchronous: via MS Teams	Orientation: Before class, students watch a video on the experiments that sparked quantum physics via discussion forum. (30%) Exercise: Students discuss the anomalies in the experiments that sparked quantum physics. (30%)	Exercise: Students identify the anomalies in the experiments that sparked quantum physics (30%)	**General Indicator:** Students can identify wave-particle duality in wave functions. **Specific Indicator:** Students can identify the need for the concept of wave-particle duality.	20

					Feedback: The lecturer gives their feedback on the discussion result and question-and-answer session via video conference. (10%)			
2	1	Wave-particle duality [1] Ch. 2	Interactive lecture, think pair share, self-study. Discussions via forum and lecture, video conference: [100 minutes]	Asynchronous via EMAS UI (independent study and discussion forums) Synchronous via Ms Teams	Orientation: Before class, students watch a video on wave-particle duality via EMAS. (30%) Exercise: Students discuss the implication of the concept of wave-particle duality via discussion forum. (30%) Feedback: The lecturer gives their	Exercise: Students identify wave-particle duality in the discussion material. (30%)	**General Indicator:** Students can identify wave-particle duality in wave functions. **Specific Indicator:** Students can identify wave-particle duality.	0

					feedback on the discussion result and question-and-answer session via video conference. (10%)			
3	1	Heisenberg uncertainty principle [1] Ch. 2	Interactive lecture, think pair share, self-study. Discussions via forum and lecture, video conference: [100 minutes]	Asynchronous via EMAS UI (independent study and discussion forums) Synchronous via Ms Teams	Orientation: Before class, students watch a video illustrating the Heisenberg uncertainty principle via EMAS. (30%) Exercise: Students discuss the Heisenberg uncertainty principle via discussion forum. (30%) Feedback: The lecturer gives their feedback on the discussion result	Exercise: Students analyze the characteristics of the Heisenberg uncertainty principle in the discussion material. (30%)	**General Indicator:** Students can identify wave-particle duality in wave functions. **Specific Indicator:** Students can identify wave-particle duality in the Heisenberg uncertainty principle.	0

					and question-and-answer session via video conference. (10%)			
4	2	Schrödinger’s equation [1] Ch. 3	Interactive lecture, think pair share, self-study. Discussions via forum and lecture, video conference: [100 minutes]	Asynchronous via EMAS UI (independent study and discussion forums) Synchronous via Ms Teams	Orientation: Before class, students watch a video on the derivation of Schrödinger’s equation via EMAS. (30%) Exercise: Students discuss the implications of Schrödinger’s equation via discussion forum. (30%) Feedback: The lecturer gives their feedback on the discussion result and question-and-answer	Exercise: Students explain Schrödinger’s equation in the discussion material. (30%)	**General Indicator:** Students can explain the concept of the wave function and Schrödinger’s equation in the motion of a free particle blocked by a one-dimensional potential. **Specific Indicator:** Students can explain Schrödinger’s equation.	15

					session via video conference. (10%)			
5	2	Free particle [1] Ch. 4	Interactive lecture, think pair share, self-study. Discussions via forum and lecture, video conference: [100 minutes]	Asynchronous via EMAS UI (independent study and discussion forums) Synchronous via Ms Teams	Orientation: Before class, students watch a video on the wave function of a free particle via EMAS. (30%) Exercise: Students discuss the characteristics and applications of the wave function of a free particle via discussion forum. (30%) Feedback: The lecturer gives their feedback on the discussion result and question-and-answer	Exercise: Students explain the characteristics of the wave function of a free particle in the discussion material. (30%)	**General Indicator:** Students can explain the concept of the wave function and Schrödinger's equation of the motion of a free particle blocked by a one-dimensional potential. **Specific Indicator:** Students can explain the concept of the wave function of a free particle.	0

					session via video conference. (10%)			
6	3	One dimensional potential [1] Ch. 4	Interactive lecture, think pair share, self-study. Discussions via forum and lecture, video conference: [100 minutes]	Asynchronous via EMAS UI (independent study and discussion forums) Synchronous via Ms Teams	Orientation: Before class, students watch a video on the derivation of a wave function via EMAS. (30%) Exercise: Students discuss the characteristics of a wave function in a one-dimensional potential via discussion forum. (30%) Feedback: The lecturer gives their feedback on the discussion result and question-	Exercise: Students explain the characteristics of a wave function in a one-dimensional potential in the discussion material. (30%)	**General Indicator:** Students can explain the concept of the eigenvalue of the wave function of a bound particle in one dimension. **Specific Indicator:** Students can explain the concept of wave functions in one dimension.	15

					and-answer session via video conference. (10%)			
7	3	Harmonic oscillator [1] Ch. 4	Interactive lecture, think pair share, self-study. Discussions via forum and lecture, video conference: [100 minutes]	Asynchronous via EMAS UI (independent study and discussion forums) Synchronous via MS Teams	Orientation: Before class, students watch a video on deriving the characteristics of the wave function of a harmonic oscillator via EMAS. (30%) Exercise: Students discuss the characteristics of the wave function of a harmonic oscillator via discussion forum. (30%) Feedback: The lecturer gives their	Exercise: Students explain the characteristics of the wave function of a harmonic oscillator in the discussion material. (30%)	**General Indicator:** Students can explain the concept of the eigenvalue and wave function of a bound particle in one dimension. **Specific Indicator:** Students can explain the concept of wave functions in a harmonic oscillator.	0

					feedback on the discussion result and question-and-answer session via video conference. (10%)			
8	**Mid-Term Exam**							
9	5	Dirac notation [1] Ch. 5	Interactive lecture, think pair share, self-study. Discussions via forum and lecture, video conference: [100 minutes]	Asynchronous via EMAS UI (independent study and discussion forums) Synchronous via MS Teams	Orientation: Before class, students watch a video on the Dirac notation via EMAS. (30%) Exercise: Students discuss the application of the Dirac notation via discussion forum. (30%) Feedback: The lecturer gives their feedback on the discussion result and question-	Exercise: Students apply the Dirac notation on the concept of wave functions in the discussion material. (30%)	**General Indicator:** Students can apply the concept of operators in harmonic oscillators, angular momentum, and N-particle systems. **Specific Indicator:** Students can apply the concept of operators.	25

					and-answer session via video conference. (10%)			
10	4	Operator methods [1] Ch. 6	Interactive lecture, think pair share, self-study. Discussions via forum and lecture, video conference: [100 minutes]	Asynchronous via EMAS UI (independent study and discussion forums) Synchronous via MS Teams	Orientation: Before class, students watch a video on the application of operator methods via EMAS. (30%) Exercise: Students discuss operator methods via discussion forum. (30%) Feedback: The lecturer gives their feedback on the discussion result and question-and-answer session via video	Exercise: Students apply operator methods to the concept of wave functions in the discussion material. (30%)	**General Indicator:** Students can apply the concept of operators in harmonic oscillators, angular momentum, and N-particle systems. **Specific Indicator:** Students can apply the concept of operators in harmonic oscillators.	0

					conference. (10%)			
11	4	Angular momentum [1] Ch. 7	Interactive lecture, think pair share, self-study. Discussions via forum and lecture, video conference: [100 minutes]	Asynchronous via EMAS UI (independent study and discussion forums) Synchronous via MS Teams	Orientation: Before class, students watch a video explaining quantum angular momentum via EMAS. (30%) Exercise: Students discuss the characteristics of quantum angular momentum via discussion forum. (30%) Feedback: The lecturer gives their feedback on the discussion result and question-and-answer session via video conference.	Exercise: Students apply quantum angular momentum in the discussion materials. (30%)	**General Indicator:** Students can apply the concept of operators in harmonic oscillators, angular momentum, and N-particle systems. **Specific Indicator:** Students can apply the concept of operators in angular momentum.	0

					(10%)			
12	4	Quantum N-particles [1] Ch. 13	Interactive lecture, think pair share, self-study. Discussions via forum and lecture, video conference: [100 minutes]	Asynchronous via EMAS UI (independent study and discussion forums) Synchronous via MS Teams	Orientation: Before class, students watch a video on the wave function of an N-particle system via EMAS. (30%) Exercise: Students discuss the characteristics of the wave function of an N-particle system via discussion forum. (30%) Feedback: The lecturer gives their feedback on the discussion result and question-and-answer session via video	Exercise: Students analyze the characteristics of the wave function of an N-particle system in the discussion material. (30%)	**General Indicator:** Students can apply the concept of operators in harmonic oscillators, angular momentum, and N-particle systems. **Specific Indicator:** Students can apply the concept of operators in N-particle systems.	0

					conference. (10%)			
13	5	3D Schrödinger’s equation [1] Ch. 8	Interactive lecture, think pair share, self-study. Discussions via forum and lecture, video conference: [100 minutes]	Asynchronous via EMAS UI (independent study and discussion forums) Synchronous via MS Teams	Orientation: Before class, students watch a video on the three-dimensional Schrödinger’s equation via EMAS. (30%) Exercise: Students discuss the implications of the three-dimensional Schrödinger’s equation via discussion forum. (30%) Feedback: The lecturer gives their feedback on the discussion result and question-and-answer session via video	Exercise: Students analyze the three-dimensional Schrödinger’s equation in the discussion material. (30%)	**General Indicator:** Students can apply the concept of wave functions in a hydrogen atom and under a three-dimensional potential. **Specific Indicator:** Students can apply the concept of wave functions in a three-dimensional potential.	25

					conference. (10%)			
14	5	Central potential [1] Ch. 8	Interactive lecture, think pair share, self-study. Discussions via forum and lecture, video conference: [100 minutes]	Asynchronous via EMAS UI (independent study and discussion forums) Synchronous via MS Teams	Orientation: Before class, students watch a video on central potential via EMAS. (30%) Exercise: Students discuss wave functions in a central potential via discussion forum. (30%) Feedback: The lecturer gives their feedback on the discussion result and question-and-answer session via video conference. (10%)	Exercise: Students analyze the characteristics of wave functions in a central potential in the discussion material. (30%)	**General Indicator:** Students can apply the concept of wave functions in a hydrogen atom and under a three-dimensional potential. **Specific Indicator:** Students can apply the concept of wave functions in a three-dimensional potential.	0

15	5	Hydrogen atom [1] Ch. 8	Interactive lecture, think pair share, self-study. Discussions via forum and lecture, video conference: [100 minutes]	Asynchronous via EMAS UI (independent study and discussion forums) Synchronous via MS Teams	Orientation: Before class, students watch a video on the derivation of the wave function of a hydrogen atom via EMAS. (30%) Exercise: Students discuss the characteristics of the wave function of a hydrogen atom. (30%) Feedback: The lecturer gives their feedback on the discussion result and question-and-answer session via video conference. (10%)	Exercise: Students analyze the wave function of a hydrogen atom. (30%)	**General Indicator:** Students can apply the concept of the wave function of a hydrogen atom and under a three-dimensional potential. **Specific Indicator:** Students can apply the concept of wave functions in a hydrogen atom.	0

16	**Final Exam**

II. Assignment Design

Week	Assignment Name	Sub-CLOs	Assignment	Scope	Working Procedure	Deadline	Outcome
3	Group Assignment 1	1	Group Assignment	Heisenberg uncertainty principle	Group homework	1 week	PowerPoint file
5	Individual Assignment 1	2	Essay	Motion of a free particle	Individual homework	1 week	Graphs and PDF file
6	Individual Assignment 2	3	Essay	One dimensional bound state	Individual homework	1 week	Graphs and PDF file
12	Group Assignment 2	4	Presentation	Angular momentum and N-particle systems	Group homework	1 week	PowerPoint file
14	Individual Assignment 3	5	Essay	Central force	Individual homework	1 week	PDF file

III. Assessment Criteria (Learning Outcome Evaluation)

Evaluation Type	Sub-CLO	Assessment Type	Frequency	Evaluation Weight (%)
Individual Assignment	2, 3, 5	Written test via EMAS	3	30
Group Assignment	1, 4	Presentation	2	20
Midterm Exam	1, 2, 3	Synchronous exam submitted via EMAS	1	25
Final Exam	4, 5	Synchronous exam submitted via EMAS	1	25
			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

Criteria	80~100	65~80	50~65	0~50
Mathematical formulation	Student can write the correct differential equation.	Student can find the correct symmetry, but the written differential equation is incorrect.	Student can find an incorrect symmetry, and the written differential equation is incorrect.	Student is unable to find the symmetry, and the written differential equation is incorrect.
Determining boundary values	Student can determine boundary values correctly.	Student can find the correct symmetry, but the written boundary values are incorrect.	Students can find an incorrect symmetry, and the written boundary values are incorrect.	Student is unable to find the symmetry, and the written boundary values are incorrect.
Implications of Quantum Properties	Student can explain quantum properties correctly.	Student can explain quantum properties less correctly.	Student is less able to explain quantum properties.	Student is unable to explain quantum properties.