TEACHING INSTRUCTIONAL DESIGN (BRP)

COURSE

SCATTERING THEORY

by

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December 2017

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

TEACHING INSTRUCTIONAL DESIGN

Course Name	Scattering Theory	**Credit(s)**	**Prerequisite course(s)**	**Requisite for course(s)**	**Integration Between Other Courses**
Course Code	SCPH604700	2	Quantum Physics 1, Introduction to Nuclear Physics	-	Scattering Theory is one of several compulsory courses in the Nuclear and Particle specialization.
Relation to Curriculum	Elective Course				
Semester	6				
Lecturer(s)	Dr. Imam Fachruddin				
Course Description	Explaining the process of particle scattering, the methods, and theoretical calculation techniques, along with numerical calculations to calculate the magnitudes in scattering, applying the capability of doing non-relativistic quantum mechanics calculations on particle scattering. Contents of this course: scattering kinematics, scattering wave function, scattering amplitude, scattering cross-section, Born approximation, Lipmann-Schwinger equation, propagators, scattering matrix, partial wave analysis, phase shift, density matrix, spin magnitude, the numerical calculation to solve the Lippmann-Schwinger equation for scattering matrix T.				

Program Learning Outcome (PLO)	
PLO-3	Applying the concepts of Theoretical Nuclear and Particle Physics
PLO-4	Formulating problems and solving Physics and its application, as well as interdisciplinary problems related to science and mathematics clusters critically, creatively, and innovatively.
PLO-7	Applying the basic concepts of physics in the community and practical life, as well as identifying and adapting to new things.
Course Learning Outcome (CLO)	
CLO-1	After finishing this course, if faced with particle scattering process problem in nuclear physics, 6^{th} term Theoretical Nuclear and Particle specialization students are able to apply (C3) quantum mechanics to formulate the scattering process of two particles, both for neither particle having spin and for particles having spin of ½ each, up to the point where the equations for the scattering cross-section and spin magnitudes are derived.
Sub-CLO(s)	
Sub-CLO 1	Explain (C2) briefly scattering processes and scattering cross-section,
Sub-CLO 2	Derive (C3) scattering kinematics in the laboratory framework and center of mass framework, along with the relationship between both frameworks,
Sub-CLO 3	Explain (C2) scattering processes using quantum mechanics,
Sub-CLO 4	Explain (C2) the concept of representation and basis,
Sub-CLO 5	Perform (C3) basis change,
Sub-CLO 6	Calculate (C3) scattering processes using partial wave analysis,
Sub-CLO 7	Calculate (C3) scattering processes using three-dimensional analysis.
Study Materials	Scattering kinematics, scattering wave function, scattering amplitude, scattering cross-section, Born approximation, Lipmann-Schwinger equation, propagators, scattering matrix, partial wave analysis, phase shift, density matrix, spin magnitude, the numerical calculation to solve the Lippmann-Schwinger equation for scattering matrix T.

Reading List	1. Liboff, R.L., Introductory Quantum Mechanics, 2nd Ed., Addison-Wesley, Reading, Massachusetts (1992). 2. Davydov, A.S., Quantum Mechanics, 2nd Ed., Pergamon Press, Oxford (1965). 3. Glöckle, W., The Quantum Mechanical Few-Body Problem, Springer Verlag, Berlin (1983). 4. Rose, M.E., Elementary Theory of Angular Momentum, Wiley, New York (1957). 5. Okubo, S. dan R.E. Marshak, Ann. Phys. 4, 166 (1958). 6. Malfliet, R.A. dan J.A. Tjon, Nucl. Phys. A127, 161 (1969). 7. Machleidt, R., Adv. Nucl. Phys. 19, 189 (1989). 8. Wiringa, R.B., V.G.J. Stoks, R. Schiavilla, Phys. Rev. C51, 38 (1995).

I. Teaching Plan

Week	Sub-CLO	Study Materials [with reference]	Teaching Method [with est. time]	Learning Experiences (*O-E-F)	Sub-CLO Achievement Indicator (*General-Specific)	Sub-CLO Weight on Course (%)
1	1	Introduction: a simple overview of scattering processes, definition and physical meaning of scattering cross-sections, explanation of the course Liboff, R.L., Introductory Quantum Mechanics, 2nd Ed., Addison-Wesley, Reading, Massachusetts (1992).	Lecturing 150 minutes	80% O, 10% E, 10% F	Students can explain the concept and scope of the Scattering Theory course.	4
2	2	Scattering kinematics, position, momentum, energy, scattering angles in the laboratory and center of mass framework, and the relation between both, Jacobian position and momentum. 1. Davydov, A.S., Quantum Mechanics, 2nd Ed., Pergamon Press, Oxford (1965). 2. Glöckle, W., The Quantum Mechanical Few-Body Problem, Springer Verlag, Berlin (1983).	Lecturing 150 minutes	70% O, 20% E, 10%F	Students can formulate scattering kinematics.	6
3	3	Wave function, scattering amplitude, and cross-sections.	Lecturing 150 minutes	70% O, 20% E, 10%F	Students can understand quantum formulations in scattering theory.	6

		Davydov, A.S., Quantum Mechanics, 2nd Ed., Pergamon Press, Oxford (1965).				
4	3	The Green function Davydov, A.S., Quantum Mechanics, 2nd Ed., Pergamon Press, Oxford (1965).	Lecturing 150 minutes	70% O, 20% E, 10%F	Students can understand and formulate methods in using the Green function for problems in scattering.	6
5	3	Rescattering process, Born approximation and series, T matrix, and the Lippmann-Schwinger equation for the T matrix. Davydov, A.S., Quantum Mechanics, 2nd Ed., Pergamon Press, Oxford (1965).	Lecturing 150 minutes	70% O, 20% E, 10%F	Students can explain and formulate the theories and approximations in scattering.	6
6	3, 4	Relation between the T matrix, M matrix, S matrix, and scattering amplitude. Representation and basis. 1. Davydov, A.S., Quantum Mechanics, 2nd Ed., Pergamon Press, Oxford (1965). 2. Glöckle, W., The Quantum Mechanical Few-Body Problem, Springer Verlag, Berlin (1983).	Lecturing 150 minutes	70% O, 20% E, 10%F	Students can explain the relationship between the T matrix, M matrix, S matrix, and scattering amplitude, along with representation and basis.	10
7	4	Basis states with the inclusion of spin magnitudes, helicity states.	Lecturing 150 minutes	70% O, 20% E, 10%F	Students can calculate basis states with spin magnitudes and helicity states.	10

		1. Davydov, A.S., Quantum Mechanics, 2nd Ed., Pergamon Press, Oxford (1965). 2. Glöckle, W., The Quantum Mechanical Few-Body Problem, Springer Verlag, Berlin (1983).				
8	**Midterm Exam**					
9	5	Basis change by utilizing the completeness relation. 1. Davydov, A.S., Quantum Mechanics, 2nd Ed., Pergamon Press, Oxford (1965). 2. Glöckle, W., The Quantum Mechanical Few-Body Problem, Springer Verlag, Berlin (1983). 3. Rose, M.E., Elementary Theory of Angular Momentum, Wiley, New York (1957).	Lecturing 150 minutes	70% O, 20% E, 10%F	Students can explain basis change by utilizing the completeness relation.	10
10	5	Basis change example for potential matrix elements. 1. Glöckle, W., The Quantum Mechanical Few-Body Problem, Springer Verlag, Berlin (1983). 2. Okubo, S. dan R.E. Marshak, Ann. Phys. 4, 166 (1958). 3. Malfliet, R.A. dan J.A. Tjon, Nucl. Phys. A127, 161 (1969).	Lecturing 150 minutes	70% O, 20% E, 10%F	Students can explain a basis change example for potential matrix elements.	10

		4. Machleidt, R., Adv. Nucl. Phys. 19, 189 (1989). 5. Wiringa, R.B., V.G.J. Stoks, R. Schiavilla, Phys. Rev. C51, 38 (1995).				
11	4	Concept of partial wave analysis. 1. Davydov, A.S., Quantum Mechanics, 2nd Ed., Pergamon Press, Oxford (1965). 2. Glöckle, W., The Quantum Mechanical Few-Body Problem, Springer Verlag, Berlin (1983).	Lecturing 150 minutes	70% O, 20% E, 10%F	Students can explain the concept of partial wave analysis.	10
12	6	Lippmann-Schwinger equation for T matrix elements in the partial wave basis. Glöckle, W., The Quantum Mechanical Few-Body Problem, Springer Verlag, Berlin (1983).	Lecturing 150 minutes	70% O, 20% E, 10%F	Students can formulate the Lippmann-Schwinger equation for T matrix elements in the partial wave basis.	6
13	6	Calculation of scattering process magnitudes. Glöckle, W., The Quantum Mechanical Few-Body Problem, Springer Verlag, Berlin (1983).	Lecturing 150 minutes	70% O, 20% E, 10%F	Students can calculate scattering process magnitudes.	4
14	7	Concept of 3D analysis, Lippmann-Schwinger equation for T matrix elements in the partial wave basis.	Lecturing 150 minutes	70% O, 20% E, 10%F	Students can formulate the Lippmann-Schwinger equation for	6

		Glöckle, W., The Quantum Mechanical Few-Body Problem, Springer Verlag, Berlin (1983).			T matrix elements in the three-dimensional basis.	
15	7	Calculation of scattering process magnitudes. Glöckle, W., The Quantum Mechanical Few-Body Problem, Springer Verlag, Berlin (1983).	Lecturing 150 minutes	30% O, 40% E, 30% F	Students can calculate scattering process magnitudes.	6
16	**Final Exam**					

*) O : Orientation

E : Exercise

F : Feedback

II. Assignment Design

Week	Assignment Name	Sub-CLOs	Assignment	Scope	Working Procedure	Deadline	Outcome
3	Individual Assignment 1	1	Problem Set	Definition of cross-section	Classwork	1x20 minutes	Worksheet
5	Individual Assignment 2	2	Problem Set	Definition and derivation of kinematic and scattering angle equations	Homework	1 x 3 days	Equation derivation
7	Individual Assignment 3	3	Problem Set	Definition, derivation, and calculation of quantum mechanics equations for scattering processes.	Homework	1 week	Equation derivation and calculation
11	Individual Assignment 4	4	Problem Set	Definition, derivation, and calculation for basis states and their characteristics.	Homework	1 week	Equation derivation
12	Group Assignment 1	5	Reading material according to reference	Calculation of potential matrix elements	Homework	1 week	Calculation
13	Individual Assignment 5	5	Problem Set	Calculation of scattering magnitudes (1)	Homework	1 week	Calculation
13	Group Assignment 2	6	Reading material according to reference	Calculation of scattering magnitudes (2)	Homework	1 week	Calculation

III. Assessment Criteria (Learning Outcome Evaluation)

Evaluation Type	Sub-CLO	Assessment Type	Frequency	Evaluation Weight (%)
Individual Assignment	1-4	Answer sheet	6	20
Group Assignment	5-6	Assessment sheet	2	20
Midterm Exam	1-3	Answer sheet	1	30
Final Exam	4-6	Answer sheet	1	30
			Total:	**Total**

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