TEACHING INSTRUCTIONAL DESIGN (BRP)

COURSE

SCATTERING THEORY

by

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PREFACE

This Teaching Instructional Design is compiled to be used as a teaching reference for the Scattering Theory course. The Scattering Theory course is one of several compulsory courses in the Nuclear and Particle Physics specialization. Following the 2012 Universitas Indonesia Undergraduate Program in Physics Competence-Based Curriculum, the Scattering Theory course is given in the 6th term.

The Scattering Theory course explains the process of particle scattering and its calculation using non-relativistic quantum mechanics. Within it is explained the methods and theoretical calculation techniques along with numerical calculations to calculate magnitudes in particle scattering. To take this course students are expected to have a knowledge of quantum mechanics and nuclear physics.

Depok, 29 August 2013

Dr. Imam Fachruddin

I. General Information

1.	Name of Program / Study Level	:	Physics / Undergraduate
2.	Course Name	:	Scattering Theory
3.	Course Code	:	SCFI603412
4.	Semester	:	6
5.	Credit	:	3 credits
6.	Teaching Method(s)	:	Lecturing
7.	Prerequisite course(s)	:	Quantum Mechanics 1, Introduction to Nuclear Physics
8.	Requisite for course(s)	:	-
9.	Integration Between Other Courses	:	Scattering Theory is one of several compulsory courses in the Nuclear and Particle specialization.
10.	Lecturer(s)	:	Dr. Imam Fachruddin
11.	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.

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

A. CLO

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.

B. Sub-CLO

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

1. explain (C2) briefly scattering processes and scattering cross-section,
2. derive (C3) scattering kinematics in the laboratory framework and center of mass framework, along with the relationship between both frameworks,
3. explain (C2) scattering processes using quantum mechanics,
4. explain (C2) the concept of representation and basis,
5. perform (C3) basis change,
6. calculate (C3) scattering processes using partial wave analysis,
7. calculate (C3) scattering processes using three-dimensional analysis.

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	Introduction: a simple overview of scattering processes, definition and physical meaning of scattering cross-sections, explanation of the course	Lecturing	150 minutes	80% O, 10% E, 10% F	4	Students can explain the concept and scope of the Scattering Theory course.	1
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.	Lecturing	150 minutes	70% O, 20% E, 10%F	6	Students can formulate scattering kinematics.	2, 3
3	3	Wave function, scattering amplitude, and cross-sections.	Lecturing	150 minutes	70% O, 20% E, 10%F	6	Students can understand quantum formulations in scattering theory.	2
4	3	The Green function	Lecturing	150 minutes	70% O, 20% E, 10%F	6	Students can understand and formulate methods in using the Green function for problems in scattering.	2
5	3	Rescattering process, Born approximation and series, T matrix, and the Lippmann-Schwinger equation for the T matrix.	Lecturing	150 minutes	70% O, 20% E, 10%F	6	Students can explain and formulate the theories and approximations in scattering.	2

6	3, 4	Relation between the T matrix, M matrix, S matrix, and scattering amplitude. Representation and basis.	Lecturing	150 minutes	70% O, 20% E, 10%F	10	Students can explain the relationship between the T matrix, M matrix, S matrix, and scattering amplitude, along with representation and basis.	2, 3
7	4	Basis states with the inclusion of spin magnitudes, helicity states.	Lecturing	150 minutes	70% O, 20% E, 10%F	10	Students can calculate basis states with spin magnitudes and helicity states.	2, 3
8	**Midterm Exam**							
9	5	Basis change by utilizing the completeness relation.	Lecturing	150 minutes	70% O, 20% E, 10%F	10	Students can explain basis change by utilizing the completeness relation.	2, 3, 4
10	5	Basis change example for potential matrix elements.	Lecturing	150 minutes	70% O, 20% E, 10%F	10	Students can explain a basis change example for potential matrix elements.	3, 5, 6, 7, 8
11	4	Concept of partial wave analysis.	Lecturing	150 minutes	70% O, 20% E, 10%F	10	Students can explain the concept of partial wave analysis.	2, 3
12	6	Lippmann-Schwinger equation for T matrix elements in the partial wave basis.	Lecturing	150 minutes	70% O, 20% E, 10%F	6	Students can formulate the Lippmann-Schwinger equation for T matrix elements in the partial wave basis.	3
13	6	Calculation of scattering process magnitudes.	Lecturing	150 minutes	70% O, 20% E, 10%F	4	Students can calculate scattering process magnitudes.	3
14	7	Concept of 3D analysis, Lippmann-Schwinger equation for T matrix	Lecturing	150 minutes	70% O, 20% E, 10%F	6	Students can formulate the Lippmann-Schwinger equation for	3

		elements in the partial wave basis.					T matrix elements in the three-dimensional basis.	
15	7	Calculation of scattering process magnitudes.	Lecturing	150 minutes	30% O, 40% E, 30% F	6	Students can calculate scattering process magnitudes.	3
16	**Final Exam**							

*) O : Orientation
E : Exercise
F : Feedback

References:

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. Assignment Design

Week	Assignment Name	Sub-CLO	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

II. 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				**100**

III. Rubric

A. Criteria for Presentation Score

Score	Presentation Delivery
85-90	The group is able to deliver the explanation logically, fluently, in a timely manner and is able to answer questions from other students and the lecturer.
75-84	The group is able to deliver the explanation logically and fluently and is able to answer questions from other students and the lecturer but delivers the explanation in a less timely manner.
65-74	The group is able to deliver the explanation fluently but is less able to deliver the reasoning behind the explanation.
55-64	Group is less able to deliver the explanation fluently, deliver it in a timely manner, and deliver the reasoning behind the explanation.
<55	

B. Criteria for Assignment and Exam Scores

Score	Answer Quality
100	The answer is very precise, and all the concepts and main components are explained completely.
76-99	The answer is fairly precise, and the concepts and main components are explained fairly completely.
51-75	The answer is less precise, and the concepts and main components are explained less completely.
26-50	The answer is poorly precise, and the concepts and main components are explained very incompletely.
<25	The answer is incorrect.