TEACHING INSTRUCTIONAL DESIGN (BRP)

COURSE

ANGULAR MOMENTUM THEORY

by

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PREFACE

The Angular Momentum Theory course is a Nuclear and Particle Physics specialization course for 7^{th} term students who have completed the Quantum Mechanics 2 course. For 14 weeks of lectures, students will receive lecture materials on the definition of angular momentum, commutative properties, and eigenvalue commutators, the summation of two angular momenta, the definition of the Clebsch-Gordan coefficient, the 3-j, 6-j, and 9-j symbols, rotation operators and their orthogonal properties, spherical harmonic functions, irreducible tensors, the Wigner-Eckart theorem, Racah coefficients, Maxwell's equations and multipole fields in spherical coordinate, static interactions and spin ½ interactions, and applications in physics. During the course, students will be given 10 assignments containing problem sets that have to be done individually (homework).

It is hoped that after completing the Angular Momentum Theory course, students will be able to understand angular momentum theory, the summation of angular momenta, the Clebsch-Gordan coefficient, the 3-j, 6-j, and 9-j symbols, and their applications within physics. The skills gained in the Angular Momentum Theory course will help students from the Theoretical Nuclear and Particle specialization in doing their research thesis, especially if their thesis topic relates to nuclear, particle, and few-body physics.

Depok, 23 August 2018

Prof. Dr. Terry Mart

I. General Information

1.	Name of Program / Study Level	:	Physics / Undergraduate
2.	Course Name	:	Angular Momentum Theory
3.	Course Code	:	SCFI602114
4.	Semester	:	7
5.	Credit	:	4 credits
6.	Teaching Method(s)	:	Lecturing, individual assignment, written exam
7.	Prerequisite course(s)	:	Quantum Mechanics 2
8.	Requisite for course(s)	:	-
9.	Integration Between Other Courses	:	-
10.	Lecturer(s)	:	Prof. Dr. Terry Mart
11.	Course Description	:	The Angular Momentum Theory course teaches students about formulating few-body angular momenta and its application within physics. The topics discussed include the definition of angular momentum, commutative properties, and eigenvalue commutators, the summation of two angular momenta, the definition of the Clebsch-Gordan coefficient, relations for the Clebsch-Gordan coefficient, calculation of the Clebsch-Gordan coefficient, the 3-j, 6-j, and 9-j symbols, rotation operators and their orthogonal properties, spherical harmonic functions, irreducible tensors, the Wigner-Eckart theorem, Racah coefficients, Maxwell's equations and multipole fields in spherical coordinate, static interactions and spin-½ interactions, and applications for nuclear systems and alpha particle emission by the nucleus.

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

A. CLO

After the completion of this course, students will be able to derive relations in angular momentum theory and apply them in problem within physics that includes quantum mechanics, nuclear physics, particle physics, and few-body physics. (PLO(s) 1, 2, 5, 6, 7)

B. Sub-CLO

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

1. derive the fundamental principles used in angular momentum theory (C3),
2. derive and calculate angular momentum operators (C3),
3. derive the coupling of two angular momenta (C3),
4. calculate and test transformation characteristics due to rotation (C3, C4),
5. derive and apply the Wigner-Eckart theorem (C3),
6. derive Racah coefficients and demonstrate their basic application (C3),
7. derive Maxwell's equations in spherical coordinates (C3),
8. apply formulations in angular momentum theory in solving problems within physics (C3).

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	Operators and unitary transformations	Lecturing	200 minutes	60% O, 20% E, 20% F	5	Students can derive the fundamental principles used in angular momentum theory.	Ref. 1 p. 3-9; Ref. 2 p. 13
2	1	Diagonalization and exponential form of operators, definition of angular momentum	Lecturing	200 minutes	60% O, 20% E, 20% F	5	Students can derive and calculate angular momentum operators.	Ref. 1 p. 10-14, Ref. 2 p. 10-30
3	1	Commutative properties and eigenvalue of commutators, physical interpretation of angular momentum	Lecturing	200 minutes	60% O, 20% E, 20% F	7	Students can derive and calculate angular momentum operators.	Ref. 1 p. 20-31, Ref. 2 p. 18-26
4	2	Summation of two angular momenta, definition of the Clebsch-Gordan coefficient	Lecturing	200 minutes	60% O, 20% E, 20% F	8	Students can derive the coupling of two angular momenta.	Ref. 1 p. 32-35; Ref. 2 p. 31-34
5	2	Relations related to the Clebsch-Gordan coefficient, calculation of the Clebsch-Gordan coefficient	Lecturing	200 minutes	60% O, 20% E, 20% F	8	Students can derive the coupling of two angular momenta.	Ref. 1 p. 37-47; Ref. 2 p. 37-43
6	3	Matrix representation of rotation operators	Lecturing	200 minutes	60% O, 20% E, 20% F	5	Students can calculate and test transformation characteristics due to rotation.	Ref. 1 p. 48-56
7	3	Rotation operator and its orthogonality	Lecturing	200 minutes	60% O, 20% E, 20% F	7	Students can calculate and test transformation characteristics due to rotation.	Ref. 1 p. 62-75
8	**Midterm Exam**							

9	4	Spherical harmonic function, irreducible tensors	Lecturing	200 minutes	60% O, 20% E, 20% F	8	Students can derive and apply the Wigner-Eckart theorem.	Ref. 1 p. 76-81; Ref. 2 p. 9, 124
10	4	Wigner-Eckart theorem, the 3-j, 6-j, and 9-j symbols	Lecturing	200 minutes	60% O, 20% E, 20% F	10	Students can derive and apply the Wigner-Eckart theorem.	Ref. 1 p. 85-93; Ref. 2 p. 4, 45-50, 92-100, 100-107
11	4	Summation of three angular momenta, Racah coefficient	Lecturing	200 minutes	60% O, 20% E, 20% F	10	Students can derive Racah coefficients and demonstrate their basic application	Ref. 1 p. 107-126; Ref. 2 p. 52, 97
12	5	Maxwell's equations and multipole fields in spherical coordinates	Lecturing	200 minutes	60% O, 20% E, 20% F	7	Students can derive Maxwell's equations in spherical coordinates.	Ref. 1 p. 127-139
13	5	Static interactions and interactions involving particles with spin-½	Lecturing	200 minutes	60% O, 20% E, 20% F	7	Students can apply formulations in angular momentum theory in solving problems within physics	Ref. 1 p. 140-149
14	6	Applications in nuclear reactions	Lecturing	200 minutes	60% O, 20% E, 20% F	7	Students can apply formulations in angular momentum theory in solving problems within physics	Ref. 1 p. 187-203
15	6	Applications in the emission of α particles by the nucleus	Lecturing	200 minutes	60% O, 20% E, 20% F	6	Students can apply formulations in angular momentum theory in solving problems within physics	Ref. 1 p. 161-186
16	**Final Exam**							

*) O : Orientation
E : Experience
F : Feedback

References:

1. M. E. Rose, *Elementary Theory of Angular Momentum*, Dover Books on Physics, reprint edition, 2011.
2. R. Edmonds, *Angular Momentum in Quantum Mechanics*, Princeton University Press, Reissue edition,1996.

IV. Assignment Design

Week	Assignment Name	Sub-CLO	Assignment	Scope	Working Procedure	Deadline	Outcome
2	Individual Assignment 1	1	Problem set	Operators and unitary transformations, diagonalization and exponential form of operators, definition of angular momentum	Individual homework	1 week	Answer sheet
3	Individual Assignment 2	1	Problem set	Commutative properties and eigenvalue of commutators, physical interpretation of angular momentum	Individual homework	1 week	Answer sheet
4	Individual Assignment 3	2	Problem set	Summation of two angular momenta, definition of the Clebsch-Gordan coefficient	Individual homework	1 week	Answer sheet
5	Individual Assignment 4	2	Problem set	Relations related to the Clebsch-Gordan coefficient, calculation of the Clebsch-Gordan coefficient	Individual homework	1 week	Answer sheet
7	Individual Assignment 5	3	Problem set	Matrix representation of rotation operators, rotation operator, and its orthogonality	Individual homework	1 week	Answer sheet
10	Individual Assignment 6	4	Problem set	Spherical harmonic function, irreducible tensors	Individual homework	1 week	Answer sheet
11	Individual Assignment 7	4	Problem set	Wigner-Eckart theorem, the 3-j, 6-j, and 9-j symbols	Individual homework	1 week	Answer sheet
12	Individual Assignment 8	4, 5	Problem set	Summation of three angular momenta, Racah coefficient	Individual homework	1 week	Answer sheet
13	Individual Assignment 9	5	Problem set	Maxwell's equations and multipole fields in spherical coordinates, static interactions, and interactions involving particles with spin-½	Individual homework	1 week	Answer sheet
15	Individual Assignment 10	6	Problem set	Applications in nuclear reactions and the emission of α particles by the nucleus	Individual homework	1 week	Answer sheet

V. Assessment Criteria (Learning Outcome Evaluation)

Evaluation Type	Sub-CLO	Assessment Type	Frequency	Evaluation Weight (%)
Individual Assignment	1-6	Answer sheet	10	30
Midterm Exam	1-3	Answer sheet	1	30
Final Exam	4-6	Answer sheet	1	40
Total				**100**

VI. Rubric

A. 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