TEACHING INSTRUCTIONAL DESIGN (BRP)

COURSE

ANGULAR MOMENTUM THEORY

by

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

TEACHING INSTRUCTIONAL DESIGN

Course Name	Angular Momentum Theory	**Credit(s)**	**Prerequisite course(s)**	**Requisite for course(s)**	**Integration Between Other Courses**
Course Code	SCPH604702	4	Quantum Physics 2	-	-
Relation to Curriculum	Elective Course				
Semester	7				
Lecturer(s)	Prof. Dr. Drs. Terry Mart				
Course Description	The Angular Momentum Theory course is given on the 7th term, comprising of the definition of angular momentum, commutative properties, and eigenvalue commutators, the summation of two angular momenta, the definition of the Clebsch-Gordan (CG) coefficient, relations related to the CG coefficient, calculation of the CG 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 coordinates, static interactions and spin ½ interactions, and applications for alpha particle emission by the nucleus and nuclear systems.				

Program Learning Outcome (PLO)	
PLO-1	Applying angular momentum theory concepts in general physics problems.
PLO-1.1	Formulating the problems in and solutions to mechanics physics, electrodynamics, electricity and magnetism.
PLO-2.1	Deriving formulas specific to the problem at hand in angular momentum.
Course Learning Outcome (CLO)	
CLO-1	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. (C3)
Sub-CLO(s)	
Sub-CLO 1	Derive the fundamental principles used in angular momentum theory. (C3)
Sub-CLO 2	Derive and calculate angular momentum operators. (C3)
Sub-CLO 3	Derive the coupling of two angular momenta. (C3)
Sub-CLO 4	Calculate and test transformation characteristics due to rotation. (C3, C4)
Sub-CLO 5	Derive and apply the Wigner-Eckart theorem. (C3)
Sub-CLO 6	Derive Racah coefficients and demonstrate their basic application. (C3)
Sub-CLO 7	Derive Maxwell's equations in spherical coordinates. (C3)
Sub-CLO 8	Apply formulations in angular momentum theory in solving problems within physics. (C3)
Study Materials	– Introduction – Hermite operators – Unitary transformation – Diagonalization of operators – Unitary operators in exponential form – Definition of angular momentum operators

	– Orbital angular momentum – Commutative properties of angular momentum operators – Eigenvalue of angular momentum operators – Physical interpretation of angular momentum – Definition of the Clebsch-Gordan coefficient – Symmetry relation for the Clebsch-Gordan coefficient – Calculation of the Clebsch-Gordan coefficient – Matrix representation of rotation operators – Clebsch-Gordan coefficient series – Determining rotation matrices – Orthogonality and rotation matrix normalization – Definition of irreducible tensor operators – Racah coefficients – Wigner-Eckart theorem – Projection theorem – Coupling of three angular momenta – Characteristics of Racah coefficients – Basic applications of Racah coefficients – Applications in electromagnetic fields – Applications in static interactions – Applications for particles with spin-½ – Applications in polarized nuclei – Applications in nuclear reactions – Applications in systems with identical particles
Reading List	1. M. E. Rose, Elementary Theory of Angular Momentum, Dover Books on Physics, 2011. 2. R. Edmonds, Angular Momentum in Quantum Mechanics, Princeton University Press, 1996. 3. A. de-Shalit and I. Talmi, Nuclear Shell Theory, Dover Publications, 2004

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** Derive the fundamental principles used in angular momentum theory. (C3)	– Hermite operators – Unitary transformation	**Face-to-face lecture** (50 minutes) **Structured individual learning** 1. Reading study materials and deriving formulas from the textbook. (50 minutes) 2. Doing problem sets in the book. (50 minutes)	**O (40%)** **Synchronous:** Face-to-face lecture via MS Teams. **E (30%)** **Asynchronous:** Reading study materials and deriving formulas from the textbook. **Asynchronous:** Problem set. **F (30%)** **Synchronous:** Question and answer session during the lecture	After the synchronous lecture, reading study materials, and doing problem sets, students can derive the fundamental principles used in angular momentum theory.	Students can apply Hermite operators and unitary transformations in solving problems within angular momentum.	50%

2	**Sub-CLO 1** Derive the fundamental principles used in angular momentum theory. (C3)	– Diagonalization of operators – Unitary operators in exponential form	**Face-to-face lecture** (50 minutes) **Structured individual learning** 1. Reading study materials and deriving formulas from the textbook. (50 minutes) 2. Doing problem sets in the book. (50 minutes)	**O (40%) Synchronous:** Face-to-face lecture via MS Teams. **E (30%) Asynchronous:** Students find reference material to answer questions in the problem set. **F (30%) Synchronous:** Question and answer session during the lecture	After the synchronous lecture, reading study materials, and doing problem sets, students can explain the fundamental principles used in angular momentum theory.	Students can diagonalize operators and derive unitary operators into exponential form.	50%
3	**Sub-CLO 2** Derive and calculate angular momentum operators. (C3)	– Definition of angular momentum operators – Orbital angular momentum	**Face-to-face lecture** (50 minutes) **Structured individual learning** 1. Reading study materials and deriving formulas from the textbook. (50 minutes)	**O (40%) Synchronous:** Face-to-face lecture via MS Teams. **E (30%) Asynchronous:** Students find reference material to	After the synchronous lecture, reading study materials, and doing problem sets, students can derive and calculate angular momentum operators.	Students can apply angular momentum and orbital angular momentum operators in solving problems within angular momentum.	50%

			2. Doing problem sets in the book. (50 minutes)	answer questions in the problem set. **F (30%) Synchronous:** Question and answer session during the lecture			
4	**Sub-CLO 2** Derive and calculate angular momentum operators. (C3)	– Commutative properties of angular momentum operators – Eigenvalue of angular momentum operators	**Face-to-face lecture** (50 minutes) **Structured individual learning** 1. Reading study materials and deriving formulas from the textbook. (50 minutes) 2. Doing problem sets in the book. (50 minutes)	**O (40%) Synchronous:** Face-to-face lecture via MS Teams. **E (30%) Asynchronous:** Students find reference material to answer questions in the problem set. **F (30%) Synchronous:** Question and answer session during the lecture	After the synchronous lecture, reading study materials, and doing problem sets, students can derive and calculate angular momentum operators.	Students can apply the commutative properties of operators in solving problems within angular momentum.	50%

5	**Sub-CLO 3** Derive the coupling of two angular momenta. (C3)	– Physical interpretation of angular momentum – Definition of the Clebsch-Gordan coefficient	**Student presentation and discussion** (50 minutes) **Structured individual learning** 1. Reading study materials and deriving formulas from the textbook. (50 minutes) 2. Doing problem sets in the book. (50 minutes)	**O (40%) Synchronous:** Face-to-face lecture via MS Teams. **E (30%) Asynchronous:** Students find reference material to answer questions in the problem set. **F (30%) Synchronous:** Question and answer session during the lecture	After the synchronous lecture, reading study materials, and doing problem sets, students can derive the coupling of two angular momenta.	Students can explain the physical interpretation of angular momentum and the definition of the Clebsch-Gordan coefficient.	50%
6	**Sub-CLO 3** Derive the coupling of two angular momenta. (C3)	– Calculation of the Clebsch-Gordan coefficient – Matrix representation of rotation operators	**Student presentation and discussion** (50 minutes) **Structured individual learning** 1. Reading study materials and deriving formulas from the textbook. (50 minutes)	**O (40%) Synchronous:** Face-to-face lecture via MS Teams. **E (30%) Asynchronous:** Students find reference material to	After the synchronous lecture, reading study materials, and doing problem sets, students can derive the coupling of two angular momenta.	Students can calculate the Clebsch-Gordan coefficient and the matrix representation of rotation operators.	50%

			2. Doing problem sets in the book. (50 minutes)	answer questions in the problem set. **F (30%)** **Synchronous:** Question and answer session during the lecture			
7	**Sub-CLO 4** Calculate and test transformation characteristics due to rotation. (C3, C4)	– Symmetry relation for the Clebsch-Gordan coefficient – Calculation of the Clebsch-Gordan coefficient	**Student presentation and discussion** (50 minutes) **Structured individual learning** 1. Reading study materials and deriving formulas from the textbook. (50 minutes) 2. Doing problem sets in the book. (50 minutes)	**O (40%)** **Synchronous:** Face-to-face lecture via MS Teams. **E (30%)** **Asynchronous:** Students find reference material to answer questions in the problem set. **F (30%)** **Synchronous:** Question and answer session during the lecture	After the synchronous lecture, reading study materials, and doing problem sets, students can calculate and test transformation characteristics due to rotation.	Students can calculate the Clebsch-Gordan coefficient and apply symmetry relations in systems with angular momentum.	50%

8	**Sub-CLO 4** Calculate and test transformation characteristics due to rotation. (C3, C4)	– Matrix representation of rotation operators – Clebsch-Gordan coefficient series	**Student presentation and discussion** (50 minutes) **Structured individual learning** 1. Reading study materials and deriving formulas from the textbook. (50 minutes) 2. Doing problem sets in the book. (50 minutes)	**O (40%) Synchronous:** Face-to-face lecture via MS Teams. **E (30%) Asynchronous:** Students find reference material to answer questions in the problem set. **F (30%) Synchronous:** Question and answer session during the lecture	After the synchronous lecture, reading study materials, and doing problem sets, students can calculate and test transformation characteristics due to rotation.	Students can apply Hermite and unitary transformations in solving problems within angular momentum.	50%
9	**Sub-CLO 5** Derive and apply the Wigner-Eckart theorem. (C3)	– Determining rotation matrices – Orthogonality and rotation matrix normalization	**Student presentation and discussion** (50 minutes) **Structured individual learning** 1. Reading study materials and deriving formulas from the textbook. (50 minutes)	**O (40%) Synchronous:** Face-to-face lecture via MS Teams. **E (30%) Asynchronous:** Students find reference material to	After the synchronous lecture, reading study materials, and doing problem sets, students can derive and apply the Wigner-Eckart theorem.	Students can determine the rotation matrix and apply orthogonality and rotation matrix normalization.	50%

			2. Doing problem sets in the book. (50 minutes)	answer questions in the problem set. **F (30%) Synchronous:** Question and answer session during the lecture			
10	**Sub-CLO 5** Derive and apply the Wigner-Eckart theorem. (C3)	– Definition of irreducible tensor operators – Racah coefficients – Wigner-Eckart theorem	**Student presentation and discussion** (50 minutes) **Structured individual learning** 1. Reading study materials and deriving formulas from the textbook. (50 minutes) 2. Doing problem sets in the book. (50 minutes)	**O (40%) Synchronous:** Face-to-face lecture via MS Teams. **E (30%) Asynchronous:** Students find reference material to answer questions in the problem set. **F (30%) Synchronous:** Question and answer session during the lecture	After the synchronous lecture, reading study materials, and doing problem sets, students can derive and apply the Wigner-Eckart theorem.	Students can apply the definition for irreducible tensor operators, Racah coefficients, and the Wigner-Eckart theorem in systems with angular momentum.	50%

11	**Sub-CLO 6** Derive Racah coefficients and demonstrate their basic application. (C3)	– Projection theorem – Coupling of three angular momenta	**Student presentation and discussion** (50 minutes) **Structured individual learning** 1. Reading study materials and deriving formulas from the textbook. (50 minutes) 2. Doing problem sets in the book. (50 minutes)	**O (40%) Synchronous:** Face-to-face lecture via MS Teams. **E (30%) Asynchronous:** Students find reference material to answer questions in the problem set. **F (30%) Synchronous:** Question and answer session during the lecture	After the synchronous lecture, reading study materials, and doing problem sets, students can derive Racah coefficients and demonstrate their basic application.	Students can apply the projection theorem and coupling of three angular momenta.	50%
12	**Sub-CLO 6** Derive Racah coefficients and demonstrate their basic application. (C3)	– Characteristics of Racah coefficients – Basic applications of Racah coefficients	**Student presentation and discussion** (50 minutes) **Structured individual learning** 1. Reading study materials and deriving formulas from the textbook. (50 minutes)	**O (40%) Synchronous:** Face-to-face lecture via MS Teams. **E (30%) Asynchronous:** Students find reference material to	After the synchronous lecture, reading study materials, and doing problem sets, students can derive Racah coefficients and demonstrate	Students can apply the characteristics of Racah coefficients.	50%

			2. Doing problem sets in the book. (50 minutes)	answer questions in the problem set. **F (30%)** **Synchronous:** Question and answer session during the lecture	their basic application.		
13	**Sub-CLO 7** Derive Maxwell's equations in spherical coordinates. (C3)	– Applications in electromagnetic fields	**Student presentation and discussion** (50 minutes) **Structured individual learning** 1. Reading study materials and deriving formulas from the textbook. (50 minutes) 2. Doing problem sets in the book. (50 minutes)	**O (40%)** **Synchronous:** Face-to-face lecture via MS Teams. **E (30%)** **Asynchronous:** Students find reference material to answer questions in the problem set. **F (30%)** **Synchronous:** Question and answer session during the lecture	After the synchronous lecture, reading study materials, and doing problem sets, students can derive Maxwell's equations in spherical coordinates.	Students can apply Maxwell's equations to electromagnetic fields.	50%

14	**Sub-CLO 7** Derive Maxwell's equations in spherical coordinates. (C3)	– Applications in static interactions – Applications for particles with spin-½	**Student presentation and discussion** (50 minutes) **Structured individual learning** 1. Reading study materials and deriving formulas from the textbook. (50 minutes) 2. Doing problem sets in the book. (50 minutes)	**O (40%) Synchronous:** Face-to-face lecture via MS Teams. **E (30%) Asynchronous:** Students find reference material to answer questions in the problem set. **F (30%) Synchronous:** Question and answer session during the lecture	After the synchronous lecture, reading study materials, and doing problem sets, students can derive Maxwell's equations in spherical coordinates.	Students can apply Maxwell's equations in spherical form on static interactions and particles with spin-½.	50%
15	**Sub-CLO 8** Apply formulations in angular momentum theory in solving problems within physics. (C3)	– Applications in polarized nuclei	**Student presentation and discussion** (50 minutes) **Structured individual learning** 1. Reading study materials and deriving formulas from the textbook. (50 minutes)	**O (40%) Synchronous:** Face-to-face lecture via MS Teams. **E (30%) Asynchronous:** Students find reference material to	After the synchronous lecture, reading study materials, and doing problem sets, students can apply formulations in angular momentum	Students can apply formulations in angular momentum theory on polarized nuclei	50%

			2. Doing problem sets in the book. (50 minutes)	answer questions in the problem set. **F (30%)** **Synchronous:** Question and answer session during the lecture	theory in solving problems within physics.		
16	**Sub-CLO 8** Apply formulations in angular momentum theory in solving problems within physics. (C3)	– Applications in nuclear reactions – Applications in systems with identical particles	**Student presentation and discussion** (50 minutes) **Structured individual learning** 1. Reading study materials and deriving formulas from the textbook. (50 minutes) 2. Doing problem sets in the book. (50 minutes)	**O (40%)** **Synchronous:** Face-to-face lecture via MS Teams. **E (30%)** **Asynchronous:** Students find reference material to answer questions in the problem set. **F (30%)** **Synchronous:** Question and answer session during the lecture	After the synchronous lecture, reading study materials, and doing problem sets, students can apply formulations in angular momentum theory in solving problems within physics.	Students can apply formulations in angular momentum theory on nuclear reactions and systems with identical particles.	50%

II. Assignment Design

Week	Assignment Name	Sub-CLOs	Assignment	Scope	Working Procedure	Deadline	Outcome
1	Assignment 1	1	Problem set	- Hermite operators - Unitary transformation	Individual Homework	1 week	Answer uploaded to EMAS
2	Assignment 2	1	Problem set	- Diagonalization of operators - Unitary operators in exponential form	Individual Homework	1 week	Answer uploaded to EMAS
3	Assignment 3	2	Problem set	- Definition of angular momentum operators - Orbital angular momentum	Individual Homework	1 week	Answer uploaded to EMAS
4	Assignment 4	2	Problem set	- Commutative properties of angular momentum operators - Eigenvalue of angular momentum operators	Individual Homework	1 week	Answer uploaded to EMAS
5	Assignment 5	3	Problem set	- Physical interpretation of angular momentum - Definition of the Clebsch-Gordan coefficient	Individual Homework	1 week	Answer uploaded to EMAS
6	Assignment 6	3	Problem set	- Calculation of the Clebsch-Gordan coefficient - Matrix representation of rotation operators	Individual Homework	1 week	Answer uploaded to EMAS

7	Assignment 7	4	Problem set	- Symmetry relation for the Clebsch-Gordan coefficient - Calculation of the Clebsch-Gordan coefficient	Individual Homework	1 week	Answer uploaded to EMAS
8	Assignment 8	4	Problem set	- Matrix representation of rotation operators - Clebsch-Gordan coefficient series	Individual Homework	1 week	Answer uploaded to EMAS
9	Assignment 9	5	Problem set	- Determining rotation matrices - Orthogonality and rotation matrix normalization	Individual Homework	1 week	Answer uploaded to EMAS
10	Assignment 10	5	Problem set	- Definition of irreducible tensor operators - Racah coefficients - Wigner-Eckart theorem	Individual Homework	1 week	Answer uploaded to EMAS
11	Assignment 11	6	Problem set	- Projection theorem - Coupling of three angular momenta	Individual Homework	1 week	Answer uploaded to EMAS
12	Assignment 12	6	Problem set	- Characteristics of Racah coefficients - Basic applications of Racah coefficients	Individual Homework	1 week	Answer uploaded to EMAS

13	Assignment 13	7	Problem set	- Applications in electromagnetic fields	Individual Homework	1 week	Answer uploaded to EMAS
14	Assignment 14	7	Problem set	- Applications in static interactions - Applications for particles with spin-½	Individual Homework	1 week	Answer uploaded to EMAS
15	Assignment 15	8	Problem set	- Applications in polarized nuclei	Individual Homework	1 week	Answer uploaded to EMAS
16	Assignment 16	8	Problem set	- Applications in nuclear reactions - Applications in systems with identical particles	Individual Homework	1 week	Answer uploaded to EMAS

III. Assessment Criteria (Learning Outcome Evaluation)

Evaluation Type	Sub-CLO	Assessment Type	Frequency	Evaluation Weight (%)
Presentation and Discussion	3, 4, 5, 6, 7, 8	- Presentation skill, - Discussion skill, - Mastery over the material	1x	50
Weekly Assignment	1, 2, 3, 4, 5, 6, 7, 8	Homework	16x	50
			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