	Universitas Negeri Surabaya Faculty of Mathematics and Natural Sciences Physics Education Undergraduate Study Program	Document Code

SEMESTER LEARNING PLAN

Courses	CODE	Course Family	Credit Weight			SEMESTER	Compilation Date
Quantum Physics	8420303069		T=3	P=0	ECTS=4.77	6	July 17, 2024
AUTHORIZATION	**SP Developer**		**Course Cluster Coordinator**			**Study Program Coordinator**	
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Learning model	**Project Based Learning**	
Program Learning Outcomes (PLO)	**PLO study program which is charged to the course**	
	Program Objectives (PO)	
	PO - 1	Develop an independent and honest character in carrying out lecture assignments in Quantum Physics
	PO - 2	Mastering the theoretical concepts of Quantum Physics in general and the theoretical concept of Heisenberg uncertainty which applies to microscopic physical systems as well as the formulation of Schrodinger wave mechanics in depth
	PO - 3	Able to formulate solutions to procedural problems related to the application of quantum theoretical concepts with Heisenberg uncertainty and Schrodinger wave mechanics to the reformulation of the theory of the hydrogen atom and other larger atoms
	PLO-PO Matrix	

P.O
PO-1
PO-2
PO-3

PO Matrix at the end of each learning stage (Sub-PO)

P.O	Week															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
PO-1																
PO-2																
PO-3																

Short Course Description	Quantum Physics studies the history of quantum concepts (a review of physical phenomena to theoretical approaches), the formulation of Schrodinger wave mechanics to solve microscopic particle physics problems without and with the presence of simple potential fields (anharmonic and harmonic), a review of the theory of the hydrogen atom through a complete solution of the Schrodinger equation radial components and spherical harmonics, explanation of the role of spin-orbit coupling in fine and superfine structure phenomena, Zeeman effect and Stark effect.

References

Main :

1. Prastowo, T. and Rahmawati, E. 2014. Lecture Notes on Quantum Physics. Unpublished work.
2. Zettili, N. 2009. Quantum Mechanics. West Sussex, UK: John Wiley and Sons.
3. Grifftiths, D. J. 1995. Introduction to Quantum Mechanics. New Jersey, US: Prentice-Hall.
4. Gasiorowicz, S. 1996. Quantum Physics. New York, US: John Wiley and Sons.
5. Liboff, R. 1980. Introductory Quantum Mechanics. Reading, US: Addison-Wesley.
6. McMahon, D. 2005. Quantum Mechanics demystified. New York, US: McGraw-Hill.

Supporters:

Supporting lecturer	Dr. Zainul Arifin Imam Supardi, M.Si. Dr. Frida Ulfah Ermawati, M.Sc. Dr. Rohim Aminullah Firdaus, S.Pd, M.Si Utama Alan Deta, S.Pd., M.Pd., M.Si.

Week-	Final abilities of each learning stage (Sub-PO)	Evaluation		Help Learning, Learning methods, Student Assignments, [Estimated time]		Learning materials [References]	Assessment Weight (%)
		Indicator	Criteria & Form	Offline (*offline*)	Online (*online*)		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	Able to understand the phenomenon of black body radiation starting from physical phenomena to classical and quantum approaches	Students are able to understand black body radiation from physical phenomena to classical and quantum approaches and are able to solve relevant problems related to black body radiation	**Criteria:** Qualitative **Form of Assessment** : Participatory Activities	Lecture, Discussion, Question and answer, Assignment 3 x 50 minutes	Lecture, Discussion, Question and answer, Assignment 3 x 50 minutes	**Material:** Thermal Radiation, Wien's Shift Law, Rayleigh-Jeans Law, Planck's Ideas **References:** *Prastowo, T. and Rahmawati, E. 2014. Lecture Notes on Quantum Physics. Unpublished work.*	5%
2	Able to understand the behavior of particles from electromagnetic waves (photons)	Students are able to understand the behavior of particles from electromagnetic waves (photons) and are able to solve relevant problems related to the photoelectric effect and Compton effect	**Criteria:** Qualitative **Form of Assessment** : Participatory Activities	Lecture, Discussion, Question and answer, Assignment 3 x 50 minutes	Lecture, Discussion, Question and answer, Assignment 3 x 50 minutes	**Material:** Photoelectric Effect, Compton Effect **References:** *Prastowo, T. and Rahmawati, E. 2014. Lecture Notes on Quantum Physics. Unpublished work.*	5%
3	Able to understand the development of atomic theory up to the phenomenon of the hydrogen atom's spectral lines, the birth of primitive quantum theory to explain the theory of the hydrogen atom	Students are able to understand the development of atomic theory up to the phenomenon of the hydrogen atom's spectral lines, the birth of primitive quantum theory to explain the theory of the hydrogen atom, and solve relevant problems related to Bohr's atomic theory.	**Criteria:** Qualitative **Form of Assessment** : Participatory Activities	Lecture, Discussion, Question and answer, Assignment 3 x 50 minutes	Lecture, Discussion, Question and answer, Assignment 3 x 50 minutes	**Material:** Atomic Model, Bohr Atomic Model, Hydrogen Atomic Line Spectrum, Principle of Correspondence **References:** *Prastowo, T. and Rahmawati, E. 2014. Lecture Notes on Quantum Physics. Unpublished work.*	5%
4	Able to understand the wave behavior of moving microscopic particles	Students are able to understand the wave behavior of moving microscopic particles and are able to solve relevant problems related to de Broglie's hypothesis	**Criteria:** Qualitative **Form of Assessment** : Participatory Activities	Lecture, Discussion, Question and answer, Assignment 3 x 50 minutes	Lecture, Discussion, Question and answer, Assignment 3 x 50 minutes	**Material:** de Broglie Hypothesis, Implications of de Broglie Hypothesis, Davisson-Germer Experiment **Library:** *Prastowo, T. and Rahmawati, E. 2014. Lecture Notes on Quantum Physics. Unpublished work.*	5%

5	Able to understand the nature of the microscopic world which is limited by the Heisenberg uncertainty principle	Students are able to understand the nature of the microscopic world which is limited by the Heisenberg uncertainty principle and are able to solve relevant problems related to the Heisenberg uncertainty principle	**Criteria:** Qualitative **Form of Assessment** : Participatory Activities	Lecture, Discussion, Question and Answer 3 x 50 minutes	Lecture, Discussion, Question and Answer 3 x 50 minutes	**Material:** Heisenberg's Uncertainty Principle, Interpretation and consequences of the Heisenberg's Uncertainty Principle **Library:** *Prastowo, T. and Rahmawati, E. 2014. Lecture Notes on Quantum Physics. Unpublished work.*	5%
6	Able to understand the basic principles of wave mechanics in the form of quantum mechanical postulates	Students are able to understand the basic principles of wave mechanics in the form of quantum mechanical postulates, and are able to calculate normalization constants and expectation values	**Criteria:** Qualitative **Form of Assessment** : Participatory Activities	Lecture, Discussion, Question and Answer 3 x 50 minutes	Lecture, Discussion, Question and Answer 3 x 50 minutes	**Material:** Operators and measurements in quantum mechanics, Wave Function, Born Interpretation, Normalization Principle, Superposition Principle, Expectation Value **References:** *Prastowo, T. and Rahmawati, E. 2014. Lecture Notes on Quantum Physics. Unpublished work.*	5%
7	Able to understand the concept of wave mechanics, the Schrodinger equation to solve several physics problems related to microscopic particles, able to reduce the conservation of energy in several simple potential cases	Students are able to understand the concept of wave mechanics, the Schrodinger equation to solve several physics problems related to microscopic particles, and are able to reduce the conservation of energy in several simple potential cases.	**Criteria:** Qualitative **Form of Assessment** : Participatory Activities	Lecture, Discussion, Question and Answer 3 x 50 minutes	Lecture, Discussion, Question and Answer 3 x 50 minutes	**Material:** Stationary state, Particles in a box, Simple potential problems, Law of continuity, Harmonic oscillator **References:** *Prastowo, T. and Rahmawati, E. 2014. Lecture Notes on Quantum Physics. Unpublished work.*	5%
8	Students are able to master the theoretical concepts of quantum physics for microscopic systems: black body thermal radiation, photoelectric effect, Compton effect, Bohr atomic model, de Broglie hypothesis, Heisenberg uncertainty	Students are able to understand and solve USS questions that are relevant to the teaching material on quantum phenomena in microscopic systems properly and correctly	**Criteria:** Quantitative	Written Test 3 x 50 minutes	Written Test 3 x 50 minutes	**Material:** Mid-semester Evaluation **References:** *Prastowo, T. and Rahmawati, E. 2014. Lecture Notes on Quantum Physics. Unpublished work.*	10%

9	Able to understand the concept of wave mechanics, Schrodinger's equation to solve several physics problems related to microscopic particles, able to derive energy conservation in several simple potential cases, able to understand analytical and algebraic methods in the case of quantum harmonic oscillators	Students are able to understand the concept of wave mechanics, the Schrodinger equation to solve several physics problems related to microscopic particles, are able to derive energy conservation in several simple potential cases, are able to understand analytical and algebraic methods to solve quantum harmonic oscillator problems	**Criteria:** Qualitative **Form of Assessment** : Participatory Activities	Lecture, Discussion, Question and Answer 3 x 50 minutes	Lecture, Discussion, Question and Answer 3 x 50 minutes	**Material:** Stationary state, Particles in a box, Simple potential problems, Law of continuity, Harmonic oscillator **References:** *Prastowo, T. and Rahmawati, E. 2014. Lecture Notes on Quantum Physics. Unpublished work.*	5%
10	Able to understand the complete solution of the 3D Schrodinger equation in the form of radial components and spherical harmonics, understand the reformulation of hydrogen atoms with spherical coordinates	Students are able to understand the complete solution of the 3D Schrodinger equation in the form of radial components and spherical harmonics, and are able to understand the reformulation of the hydrogen atom with spherical coordinates	**Criteria:** Qualitative **Form of Assessment** : Participatory Activities	Lecture, Discussion, Question and Answer 3 x 50 minutes	Lecture, Discussion, Question and Answer 3 x 50 minutes	**Material:** Schrodinger's equation in a spherical coordinate system, Review of the theory of the hydrogen atom. **Reference:** *Prastowo, T. and Rahmawati, E. 2014. Lecture Notes on Quantum Physics. Unpublished work.*	5%
11	Able to understand the complete solution of the 3D Schrodinger equation in the form of radial components and spherical harmonics, understand the reformulation of hydrogen atoms with spherical coordinates	Students are able to understand the complete solution of the 3D Schrodinger equation in the form of radial components and spherical harmonics, and are able to understand the reformulation of the hydrogen atom with spherical coordinates	**Criteria:** Qualitative **Form of Assessment** : Participatory Activities	Lecture, Discussion, Question and Answer 3 x 50 minutes	Lecture, Discussion, Question and Answer 3 x 50 minutes	**Material:** Schrodinger's equation in a spherical coordinate system, Review of the theory of the hydrogen atom. **Reference:** *Prastowo, T. and Rahmawati, E. 2014. Lecture Notes on Quantum Physics. Unpublished work.*	5%
12	Able to understand the reformulation of the hydrogen atom with spherical coordinates, able to understand the importance of orbital and spin angular momentum and total angular momentum as a complete picture of the quantum theory of the hydrogen atom	Able to understand the reformulation of the hydrogen atom with spherical coordinates, able to understand the importance of orbital and spin angular momentum and total angular momentum as a complete picture of the quantum theory of the hydrogen atom	**Criteria:** Qualitative **Form of Assessment** : Participatory Activities	Lecture, Discussion, Question and Answer 3 x 50 minutes	Lecture, Discussion, Question and Answer 3 x 50 minutes	**Material:** Schrodinger's equation in a spherical coordinate system, Review of hydrogen atomic theory, Orbital angular momentum, Spin angular momentum, Total angular momentum **References:** *Prastowo, T. and Rahmawati, E. 2014. Lecture Notes on Quantum Physics. Unpublished work.*	5%

13	Able to understand the reformulation of the hydrogen atom with spherical coordinates, able to understand the importance of orbital and spin angular momentum and total angular momentum as a complete picture of the quantum theory of the hydrogen atom	Able to understand the reformulation of the hydrogen atom with spherical coordinates, able to understand the importance of orbital and spin angular momentum and total angular momentum as a complete picture of the quantum theory of the hydrogen atom	**Criteria:** Qualitative **Form of Assessment** : Participatory Activities	Lecture, Discussion, Question and Answer 3 x 50 minutes	Lecture, Discussion, Question and Answer 3 x 50 minutes	**Material:** Schrodinger's equation in a spherical coordinate system, Review of hydrogen atomic theory, Orbital angular momentum, Spin angular momentum, Total angular momentum **References:** *Prastowo, T. and Rahmawati, E. 2014. Lecture Notes on Quantum Physics. Unpublished work.*	5%
14	Able to apply the concept of quantum mechanics to explain several phenomena in the spectrum of hydrogen atoms and other larger atoms	Students are able to apply the concept of quantum mechanics to explain several phenomena in the spectrum of hydrogen atoms and other larger atoms (fine and superfine structure, Zeeman effect and Stark effect)	**Criteria:** Qualitative **Form of Assessment** : Participatory Activities	Lecture, Discussion, Question and Answer 3 x 50 minutes	Lecture, Discussion, Question and Answer 3 x 50 minutes	**Matter:** Fine structure, relativistic correction, role of spin, spinorbit coupling, Zeeman effect, Stark effect **Reader:** *Prastowo, T. and Rahmawati, E. 2014. Lecture Notes on Quantum Physics. Unpublished work.*	5%
15	Able to apply the concept of quantum mechanics to explain several phenomena in the spectrum of hydrogen atoms and other larger atoms	Students are able to apply the concept of quantum mechanics to explain several phenomena in the spectrum of hydrogen atoms and other larger atoms (fine and superfine structure, Zeeman effect and Stark effect)	**Criteria:** Qualitative **Form of Assessment** : Participatory Activities	Lecture, Discussion, Question and Answer 3 x 50 minutes	Lecture, Discussion, Question and Answer 3 x 50 minutes	**Matter:** Fine structure, relativistic correction, role of spin, spinorbit coupling, Zeeman effect, Stark effect **Reader:** *Prastowo, T. and Rahmawati, E. 2014. Lecture Notes on Quantum Physics. Unpublished work.*	5%
16	Able to master the theoretical concepts of quantum physics	1. able to understand the concept of wave mechanics, Schrodinger's equation to solve several physics problems related to microscopic particles, able to derive energy conservation in several simple potential cases, able to understand analytical and algebraic methods to solve quantum harmonic oscillator problems 2. able to	**Criteria:** Quantitative	Written Test 3 x 50 minutes	Written Test 3 x 50 minutes	**Material:** Final Semester Evaluation **References:** *Prastowo, T. and Rahmawati, E. 2014. Lecture Notes on Quantum Physics. Unpublished work.*	20%

		understand the complete solution of the 3D Schrodinger equation in the form of radial components and spherical harmonics, able to understand the reformulation of the hydrogen atom with spherical coordinates 3. able to understand the reformulation of the hydrogen atom with spherical coordinates, able to understand the importance of orbital and spin angular momentum and total angular momentum as a complete picture of the quantum theory of the hydrogen atom 4. able to apply the concepts of quantum mechanics to explain several phenomena in the spectrum of hydrogen atoms and other larger atoms (fine and super fine structure, Zeeman effect and Stark effect)						

Evaluation Percentage Recap: Project Based Learning

No	Evaluation	Percentage
1.	Participatory Activities	70%
		70%

Notes

1. **Learning Outcomes of Study Program Graduates (PLO - Study Program)** are the abilities possessed by each Study Program graduate which are the internalization of attitudes, mastery of knowledge and skills according to the level of their study program obtained through the learning process.
2. **The PLO imposed on courses** are several learning outcomes of study program graduates (CPL-Study Program) which are used for the formation/development of a course consisting of aspects of attitude, general skills, special skills and knowledge.
3. **Program Objectives (PO)** are abilities that are specifically described from the PLO assigned to a course, and are specific to the study material or learning materials for that course.

4. **Subject Sub-PO (Sub-PO)** is a capability that is specifically described from the PO that can be measured or observed and is the final ability that is planned at each learning stage, and is specific to the learning material of the course.
5. **Indicators for assessing** ability in the process and student learning outcomes are specific and measurable statements that identify the ability or performance of student learning outcomes accompanied by evidence.
6. **Assessment Criteria** are benchmarks used as a measure or measure of learning achievement in assessments based on predetermined indicators. Assessment criteria are guidelines for assessors so that assessments are consistent and unbiased. Criteria can be quantitative or qualitative.
7. **Forms of assessment:** test and non-test.
8. **Forms of learning:** Lecture, Response, Tutorial, Seminar or equivalent, Practicum, Studio Practice, Workshop Practice, Field Practice, Research, Community Service and/or other equivalent forms of learning.
9. **Learning Methods:** Small Group Discussion, Role-Play & Simulation, Discovery Learning, Self-Directed Learning, Cooperative Learning, Collaborative Learning, Contextual Learning, Project Based Learning, and other equivalent methods.
10. **Learning materials** are details or descriptions of study materials which can be presented in the form of several main points and sub-topics.
11. **The assessment weight** is the percentage of assessment of each sub-PO achievement whose size is proportional to the level of difficulty of achieving that sub-PO, and the total is 100%.
12. TM=Face to face, PT=Structured assignments, BM=Independent study.