TEACHING INSTRUCTIONAL DESIGN (BRP)

COURSE

MODERN PHYSICS

by

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PREFACE

The Course Plan or BRP contains a lesson plan for one semester. BRP is prepared as a reference course of Modern Physics course in Undergraduate in Physics FMIPA UI, followed by physics student of 3rd semester, on the requirement that students have taken Physics Elementary 2, Basic Mathematics 2.

In the Modern Physics course, students will be taught that the separation of waves and particles is in the classical Schrodinger's Physics. The settlement of the Schrodinger equation gives a picture of the micro state, so that the structure of Hydrogen atoms, many electron atoms, molecules cannot be maintained for the micro state. Experiments show that wave-particle dualism applies to atomic states, and atomic equations and nuclei are to be explained. Modern Physics Lecture is a prerequisite for the subject of Quantum Mechanics, Solid Physics.

This book is structured as a document to supplement the 2016 Curriculum.
With the establishment of this BRP, is expected to be a reference process of learning for lecturers and learners for college students in particular and for people who want to learn it.

Depok, 22 December 2017

Dedi Suyanto, Ph.D.

I. General Information

1.	Name of Program / Study Level	:	Physics / Undergraduate
2.	Course Name	:	Modern Physics
3.	Course Code	:	SCFI602111
4.	Term	:	3
5.	Credit	:	3 credits
6.	Teaching Method	:	Lecturing, individual- and group-assignments, written exam
7.	Prerequisite course(s)	:	Basic Physics 2, Basic Mathematics 2
8.	Requisite for course(s)	:	Quantum Mechanics, Solid State Physics
9.	Integration Between Other Courses	:	None
10.	Lecturer	:	Dedi Suyanto, Ph.D.
11.	Course Description	:	Modern Physics is a compulsory subject in Undergraduate Program in Physics underlying Advanced Physics courses such as Quantum Mechanics and Solid Physics. The contents of this course include the results of classical physics until late 1900, the special theory of relativity, the nature of particle-wave and particle wave properties, atomic modeling and the introduction of quantum mechanics in the form of Schrodinger equations in Hydrogen atom model and atomic spectroscopy; many electron atoms, molecules. Radioactivity and their applications.

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

A. CLO

Students are able to solve Modern Physics problems and to explain the phenomena and its applications in the areas of nuclear and particle, material, instrumentation, and medical Physics.

B. Sub-CLOs

1. To distinguish the basic concepts of Classical Physics and Modern Physics. (C2).
2. To explain the basic concept special theory of relativity. (C2)
3. To explain the concept of wave particle properties and experimental results underlying quantum theory. (C3)
4. To explain the various kinds of atomic model development based on experimental results. (C3)
5. To explain the concept of wave particle properties. (C3)
6. To apply Schrodinger's equations in quantum mechanics to model hydrogen atom. (C3)
7. To explain the basic principles of atomic and molecular spectroscopy (C2)
8. To explain the structure nucleon, nuclear reaction and radioactivity (C2)

III. Teaching Plan

Week	Sub-CLO	Study Materials	Teaching Method	Time Required	Learning Experiences (*O-E-F)	Sub-CLOWeight on Course (%)	Sub-CLO Achievement Indicator	References
1	1	Review of classical Physics and the initial time of Modern Physics	Lecturing	150 minutes	70% O, 30% F	6	To explain the different of classical and modern physics	1) Chap. 1 2) Chap. 1
2	2	Special Theory of Relativity	Lecturing	150 minutes	70% O, 30% F	6	To explain the experiments underlying the special theory of relativity and understand the concept of Einstein's special theory of relativity	1) Chap. 2 2) Chap. 2 3) Chap. 1
3	3	The nature of particle waves and experimental results underlying quantum theory	Lecturing	150 minutes	70% O, 30% F	6	To explain the nature of particle waves and experimental results underlying quantum theory	1) Chap. 3 2) Chap. 3 3) Chap.2
4	4	Atomic Structure	Lecturing	150 minutes	70% O, 30% F	6	To explain and distinguish the atomic model Thomson, Rutherford, the classic atomic model, and the Bohr atom model for Hydrogen	1) Chap. 4 2) Chap. 6 3) Chap. 4
5	5	Wave-Particle dualism	Lecturing	150 minutes	70% O, 30% F	6	To explain and distinguish the concept of particle wave dualism	1) Chap. 5 2) Chap. 4 3) Chap. 3
6	6	Introduction of Quantum Mechanics	Lecturing	150 minutes	70% O, 30% F	10	To explain introductory of quantum mechanics	1) Chap. 6 2) Chap. 5

								3) Chap. 5
7	6	Introduction of Quantum Mechanics	Lecturing	150 minutes	70% O, 30% F	10	To construct the concept of harmonic oscillator and perturbation theory	1) Chap. 6 2) Chap. 5 3) Chap. 5
8	**Mid-Term Exam**							
9	6	Hydrogen Atom	Lecturing	150 minutes	70% O, 30% F	10	To find solutions to Schrodinger equations for Hydrogen atom	1) Chap. 7 2) Chap. 7 3) Chap. 6
10	6	Hydrogen Atom	Lecturing	150 minutes	70% O, 30% F	10	To identify quantum numbers and Zeeman effects	1) Chap.7 2)Chap. 7 3) Chap. 6
11	7	Atom with Many Electrons	Lecturing	150 minutes	70% O, 30% F	10	To illustrate the atomic structure and the periodic table	1) Chap. 8 2) Chap. 8 3) Chap. 7
12	7	Atom with Many Electrons	Lecturing	150 minutes	30% O, 40% E, 30% F	6	To explain the total angular momentum and Zeeman anomaly effects	1) Chap. 8 2) Chap. 8 3) Chap. 7
13	7	Molecules	Lecturing	150 minutes	30% O, 40% E, 30% F	4	To explain the molecular bonds and spectrum of molecular vibrations	1) Chap. 10 2) Chap. 9 3) Chap. 8, 10
14	7	Molecules	Lecturing	150 minutes	30% O, 40% E, 30% F	6	To explain the Laser and its applications	1) Chap. 10 2) Chap. 9 3) Chap. 8, 10

15	8	Nuclear Physics, Radioactivity, and Application	Lecturing	150 minutes	30% O, 40% E, 30% F	4	To explain nuclear physics, calculate nuclear reactions, and their application	1) Chap. 12 2) Chap.13
16	**Final Exam**							

*) O : Orientation
E : Exercise
F : Feedback

References:

1) Thornton, S.T. and Rex, A.2006. *Modern Physics for Scientists and Engineers.* 3rd edition, Singapore: Thomson.
2) Krane, K. 1996. *Modern Physics*. 2nd edition, 1996, New York: John Wiley & Sons.
3) Beiser, A. 1995. *Concept of Modern Physics*. 5th edition, New York: Mc Graw Hill.

IV. Assignment Design

Week	Assignment Name	Sub-CLO	Assignment	Scope	Working Procedure	Deadline	Outcome
3	Individual - Assignment 1	2	Problem set	Ether, Michelson-Morley experiment, special theory of relativity	Homework	1 week	Homework answer sheet
5	Individual - Assignment 2	3	Problem set		Homework	1 week	Homework answer sheet
7	Individual - Assignment 3	4	Problem set	Atomic Model	Homework	1 week	Homework answer sheet
11	Individual-Assignment 4	5	Problem set	Wave-particle dualism	Homework	1 week	Homework answer sheet
12	Group-Assignment 1	6	Reading materials	Schrodinger equation	Group discussion consist of 3-4 students	2 weeks	Presentation file in *power point* format
13	Individual-Assignment 5	6	Problem set	Hydrogen Atom	Homework	1 week	Homework answer sheet
13	Group-Assignment 2	7	Reading materials	Atom with many electrons	Group discussion consist of 3-4 students	2 weeks	Presentation file in *power point* format
15	Individual-Assignment 6	8	Problem set	Atomic nuclei and radioactivity	Homework	1 week	Homework answer sheet

V. 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
Mid-Term Exam	1-3	Answer sheet	1	30
Final Exam	4-6	Answer sheet	1	30
Total				**100**

VI. Rubrics

A. Criteria of Essay Score

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

VII. Appendix: Example of Exam Problems

A. Mid-Semester Exam

1. Electron had been accelerated after passed from a space with potential 50,000 volts. The initial velocity of the electron was zero, determine:
   a) Electron velocity with relativistic kinetic form of energy
   b) Electron velocity with a classical kinetic form of energy
   c) what do you think about the difference of the value obtained?

2. A light source with a wavelength λ illuminates a metal and remove a photoelectron with 1 eV maximum kinetic energy. The second light source with a half-wavelength remove a photoelectron with 4 eV maximum kinetic energy. Specify:
   a) The metal work function
   b) The wavelength of the light
   c) The cut off frequency

3. If the proton has a kinetic energy of 500 k eV, specify:
   a) Momentum of the proton
   b) Speed of the proton
   c) De Broglie wavelength of the proton
   d) De Broglie wave group velocity.

4. An electron trapped in an infinite potential well that has a width of 1 nm. If the electron is initially in the excitation state of n = 4, find 6 possible values of the photon energy irradiated in eV when it is down to the ground state (n = 1).

B. Final-Semester Exam

1. The electron in a Hydrogen atom is in a 3d state of excitation in a radiative transition to a 2p energy level.
    a) Draw the energy levels of 3d and 2p state in an energy level diagram if it is in space with an external magnetic field B = 0, regardless of spin orbit interactions.
    b) Determine the energy (in E_0) generated in the state of a radiative transition under conditions (a).
    c) Show the separation of energy levels of 3d and 2p in one energy level diagram and calculate its energy if located in space with the external magnetic field B = 2T, regardless of spin orbit interaction.
    d) List the conditions that are allowed under condition (c) and show in the energy level diagram above.
    e) Determine the energy (in E_0 and μ_0) generated in the event of a radiative transition under condition (c).
    f) Show the separation of energy levels of 3d and 2p in one energy level diagram and calculate its energy if located in space with the external magnetic field B = 0, considerate the spin orbit interaction.
    g) List the transitional conditions allowed under (i) and indicate in the energy level diagram above.
    h) Show the separation of energy levels of 3d and 2p in one energy level diagram and calculate its energy if located in space with the external magnetic field B = 2T, considerate the spin orbit interaction.
    i) List the transitional conditions allowed under (i) and indicate in the energy level diagram above.

2. Using the data in table 1, specify:
    a) The difference between the vibrational energy level of the diatomic molecule CO.
    b) The temperature required to thermally excite this vibrational energy level, if the molecule is considered a one-dimensional oscillator.

    By absorbing certain electromagnetic waves the CO molecule undergoes a transition of the rotational energy level from state $l = 3\ to\ l = 2$ by $1.43\ eV$. If known atomic mass $C = 12.00u$ and atomic mass $O = 15.99u$. Specify:

    c) the wavelength of the photon required for the excitation
    d) The inertia moment of CO molecule
    e) the average distance of the center of the C atoms and the O atoms

Table [illegible] Vibrational [illegible] and Effective [illegible]

Molecule	Frequency (Hz), $n = 0$ to $n = 1$	Force Constant (N/m)
HF	8.72×10^{13}	970
HCl	8.66×10^{13}	480
HBr	7.68×10^{13}	410
HI	6.69×10^{13}	320
CO	6.42×10^{13}	1860
NO	5.63×10^{13}	1530

From G. M. Barrow, *The Structure of Molecules*, New York, Benjamin (1963).

3. Assume all ^{206}Pb samples in uranium mines are the decay results of ^{238}U with half-life of ^{238}U is 4.5 10^9 years and the ratio of $^{206}Pb/\,^{238}U$ is 0.6. Determine the age of the mine