TEACHING INSTRUCTIONAL DESIGN (BRP) COURSE

Classical Mechanics

by

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UNIVERSITAS INDONESIA
Faculty of Mathematics and Natural Sciences
Physics Undergraduate Study Program

TEACHING DESIGN BOOK

COURSE	Classical Mechanics	**Credit(s)**	**Prerequisite course(s)**	**Requisite for course(s)**	**Integration Between Other Courses**
COURSE CODE	SCPH602223	4 credits	Basic Physics 1, Mathematical Physics 2, Mathematical Physics 3	Classical Field Theory, Spectroscopy A	
Course Cluster	Compulsory				
Semester	4				
Lecturer(s)	Handhika Satrio Ramadhan, Ph.D				

Course Description	Classical Mechanics is a compulsory course for the Physics study program that discusses mechanical phenomena in the low energy and macroscopic. After completing this course, students are required to understand and apply Newtonian and Hamiltonian formalisms in solving various dynamical physics problems. This course will discuss Newtonian mechanics for point particles, gravity, calculus of variations, Lagrangian mechanics, Hamilton's equations, central forces, dynamics of particle systems, motion in non-inertial frames of reference, and the dynamics of solid bodies.
LO-STUDY PROGRAM charged to the course	
CLO-1	Applying the concept of classical physics to solve general physics problems
CLO-2	Applying mathematical methods to solve physics problems analytical or numerical
CLO-3	Applying the knowledge of physics to society and practical lives, as well as identifying and adapting with new discoveries in the field of classical physics
Course Learning Outcomes (CLO)	
CLO	Students are competent to solve dynamical physics problems by using the formalism of Newtonian or Lagrangian-Hamiltonian (C3).
Sub-CLO	

Sub- CLO 1	Competent in explaining motion phenomena in 2D and 3D for point particles and finding the solution of equations of motion by using Newton's law (C3).
Sub- CLO 2	Competent to find the solution of the gravitational field by mass distribution, and to find the equation of motion of the particle under the effect of gravity (C3).
Sub- CLO 3	Competent in applying Calculus of Variation to find the optimum solution in physics and its application, as well as competent in applying the Least Action Principle in determining the motion equation of the dynamical system (C3).
Sub- CLO 4	Competent to find the solution of orbital equations by the effect of central force whether in the constrained system or scattering, and competent in solving the dynamics of orbital problems.
Sub- CLO 5	Mampu menganalisis dinamika sistem partikel di kerangka acuan LAB maupun pusat massa (C3). Competent to analyze dynamical system of particles in the LAB frame of reference or center of mass (C3).
Sub- CLO 6	Competent in explaining the phenomena of motion in the non-inertial frame of reference and finding the trajectory of the particle motion under the effect of Coriolis force (C3).
Sub- CLO 7	Competent in analyzing the dynamics of rigid body and deriving the equation of motions by using Lagrangian method (C3).

Lesson: Lesson Materials	1. The dynamics of motion of point particles and Newton's laws. 2. Gravity. 3. Calculus of Variations and Hamilton's Principle. 4. Central forces. 5. Particle system dynamics. 6. Motion in a non-inertial frame of reference. 7. Rigid body dynamics.

References	**Required:** 1. J. B. Marion and S. T. Thornton, *Classical Dynamics of Particles and Systems*, 5th ed, Thomson Brooks/Cole, 2004. 2. V. Barger and M. Olsson, *Classical Mechanics: A Modern Perspective*, 2nd ed, McGraw-Hill, 1995. **Additional:** 1. D. Morin, *Introduction to Classical Mechanics with Problems and Solutions*, 1st ed, Cambridge University Press, 2008. 2. R. D. Gregory, *Classical Mechanics*, 1st ed, Cambridge University Press, 2006.

RENCANA PEMBELAJARAN

***Wk**	**Sub-CLO (Expected final competence)**	**Study Material (Learning materials) [Reference]**	**Study Method [Time Estimation]**	**Learning Experience**	**Outcome Indicator sub-CLO**	**Quality of application of sub-CLO in the Course**
				Orientation; Exercise; Feedback	**General Indicators; Special Indicators**	

1	Sub-CLO 1	Introduction, presenting the contract lecture, and review vector analysis **[Reference]** Chapter 1 required textbook	Asynchronous using recorded videos uploaded to youtube and EMAS UI (self-study & discussion forums) Synchronous via MS Teams	**Orientation:** Students can view files, watch videos or use chat rooms via EMAS (30%) **Exercise:** Students discuss via MS-TEAMS or use chat rooms via EMAS and study the literature on their own checking concepts that are not clear (50%) **Feedback:** Lecturers respond to discussions via MS-TEAMS or use chat rooms via EMAS (20%)	**General Indicator:** Students are competent in understanding algebra operation and vector calculus as well as its relation with the applications of mechanics	5%

2	Sub-CLO 1	Kinematics in 2D and 3D, dynamics in 2D and 3D, Newton's laws of motion **[Reference]** Chapter 2 required textbook	Asynchronous using recorded videos uploaded to youtube and EMAS UI (self-study & discussion forums) Synchronous via MS Teams	**Orientation:** Students can view files, watch videos or use chat rooms via EMAS (30%) **Exercise:** Students discuss via MS-TEAMS or use chat rooms via EMAS and study the literature on their own checking concepts that are not clear (50%) **Feedback:** Lecturers respond to discussions via MS-TEAMS or use chat rooms via EMAS (20%)	Students are competent to describe the phenomena of motion and to find the solution of equation of motion with the formalism of Newtonian	10%

3	Sub-CLO 2	Gravitational force, gravitational field due to point mass, gravitational field around a continuous mass distribution, gravitational potential and equipotential surface, tides of waves **[Reference]** Chapter 5 required textbook	Asynchronous using recorded videos uploaded to youtube and EMAS UI (self-study & discussion forums) Synchronous via MS Teams	**Orientation:** Students can view files, watch videos or use chat rooms via EMAS (30%) **Exercise:** Students discuss via MS-TEAMS or use chat rooms via EMAS and study the literature on their own checking concepts that are not clear (50%) **Feedback:** Lecturers respond to discussions via MS-TEAMS or use chat rooms via EMAS (20%)	Students are competent in obtaining the field function of gravity from continuous distribution of mass	5%

4	Sub-CLO 3	Review of calculus of variations, Euler's equation, brachistochrone, geodesics, Euler's equation with constraints **[Reference]** Chapter 6 required textbook	Asynchronous using recorded videos uploaded to youtube and EMAS UI (self-study & discussion forums) Synchronous via MS Teams	**Orientation:** Students can view files, watch videos or use chat rooms via EMAS (30%) **Exercise:** Students discuss via MS-TEAMS or use chat rooms via EMAS and study the literature on their own checking concepts that are not clear (50%) **Feedback:** Lecturers respond to discussions via MS-TEAMS or use chat rooms via EMAS (20%)	Students are competent in applying the principle of optimization in mathematics or applied physics	15%

5	Sub-CLO 3	Hamilton's Principle, Least Action Principle, Euler-Lagrange equation, Newtonian mechanics equivalence and Hamiltonian mechanics, virial theorem **[Reference]** Chapter 7 required textbook	Asynchronous using recorded videos uploaded to youtube and EMAS UI (self-study & discussion forums) Synchronous via MS Teams	**Orientation:** Students can view files, watch videos or use chat rooms via EMAS (30%) **Exercise:** Students discuss via MS-TEAMS or use chat rooms via EMAS and study the literature on their own checking concepts that are not clear (50%) **Feedback:** Lecturers respond to discussions via MS-TEAMS or use chat rooms via EMAS (20%)	Students are competent in deriving the equations of motions in mechanics through the Principle of Hamilton / Least Action Principle	

6	Sub-CLO 4	Central force, Kepler's law, Binet's equation, effective potential, orbital solution due to central force: conic section. **[Reference]** Chapter 8 required textbook	Asynchronous using recorded videos uploaded to youtube and EMAS UI (self-study & discussion forums) Synchronous via MS Teams	**Orientation:** Students can view files, watch videos or use chat rooms via EMAS (30%) **Exercise:** Students discuss via MS-TEAMS or use chat rooms via EMAS and study the literature on their own checking concepts that are not clear (50%) **Feedback:** Lecturers respond to discussions via MS-TEAMS or use chat rooms via EMAS (20%)	Students are competent: in deriving Kepler's laws as the consequences of central force, analyzing the type of orbit trajectory based on effective potential, finding the solution of orbital trajectory equation	15%

7	Sub-CLO 4	Stability of orbits, orbital dynamics, solution of central force scattering, Rutherford scattering. **[Reference]** Chapter 8-9 required textbook	Asynchronous using recorded videos uploaded to youtube and EMAS UI (self-study & discussion forums) Synchronous via MS Teams	**Orientation:** Students can view files, watch videos or use chat rooms via EMAS (30%) **Exercise:** Students discuss via MS-TEAMS or use chat rooms via EMAS and study the literature on their own checking concepts that are not clear (50%) **Feedback:** Lecturers respond to discussions via MS-TEAMS or use chat rooms via EMAS (20%)	Students are competent in: analyzing the stability of orbit, determining the optimum trajectory in orbital dynamics, and deriving the cross-section of Rutherford scattering	
8	**Midterm Exam**					

9	Sub-CLO 5	Center of mass, conservation of momentum and energy for particle systems. **[Reference]** Chapter 9 required textbook	Asynchronous using recorded videos uploaded to youtube and EMAS UI (self-study & discussion forums) Synchronous via MS Teams	**Orientation:** Students can view files, watch videos or use chat rooms via EMAS (30%) **Exercise:** Students discuss via MS-TEAMS or use chat rooms via EMAS and study the literature on their own checking concepts that are not clear (50%) **Feedback:** Lecturers respond to discussions via MS-TEAMS or use chat rooms via EMAS (20%)	Students are competent: in determining the center of mass of particle systems whether discrete or continuous, deriving the conservation of (linear and angular) momentum and energy theorem for particle systems	15%

10	Sub-CLO 5	Elastic collisions in 2D and 3D space in the CM (center of mass) and LAB (at rest) frames. **[Reference]** Chapter 9 required textbook	Asynchronous using recorded videos uploaded to youtube and EMAS UI (self-study & discussion forums) Synchronous via MS Teams	**Orientation:** Students can view files, watch videos or use chat rooms via EMAS (30%) **Exercise:** Students discuss via MS-TEAMS or use chat rooms via EMAS and study the literature on their own checking concepts that are not clear (50%) **Feedback:** Lecturers respond to discussions via MS-TEAMS or use chat rooms via EMAS (20%)	Students are competent: in analyzing elastic collisions between two particles (or more) in 2D and 3D in the frame of CM or LAB, deriving the cross-section of Rutherford scattering in the CM or LAB frame.	

11	Sub-CLO 6	System of coordinates, fictitious force, Coriolis force. **[Reference]** Chapter 10 required textbook	Asynchronous using recorded videos uploaded to youtube and EMAS UI (self-study & discussion forums) Synchronous via MS Teams	**Orientation:** Students can view files, watch videos or use chat rooms via EMAS (30%) **Exercise:** Students discuss via MS-TEAMS or use chat rooms via EMAS and study the literature on their own checking concepts that are not clear (50%) **Feedback:** Lecturers respond to discussions via MS-TEAMS or use chat rooms via EMAS (20%)	Students are competent in deriving the equation of force in the non-inertial frame of reference	15%

12	Sub-CLO 6	Projectile trajectory under the effect of earth rotation, Foucault pendulum. **[Reference]** Chapter 10 required textbook	Asynchronous using recorded videos uploaded to youtube and EMAS UI (self-study & discussion forums) Synchronous via MS Teams	**Orientation:** Students can view files, watch videos or use chat rooms via EMAS (30%) **Exercise:** Students discuss via MS-TEAMS or use chat rooms via EMAS and study the literature on their own checking concepts that are not clear (50%) **Feedback:** Lecturers respond to discussions via MS-TEAMS or use chat rooms via EMAS (20%)	Students are competent to find the solution of projectile trajectory under the effect of perturbed Coriolis force	

13	Sub-CLO 7	Coordinates of the center of mass of the rigid body, the kinetic energy of the rigid body, the inertia tensor. **[Reference]** Chapter 11 required textbook	Asynchronous using recorded videos uploaded to youtube and EMAS UI (self-study & discussion forums) Synchronous via MS Teams	**Orientation:** Students can view files, watch videos or use chat rooms via EMAS (30%) **Exercise:** Students discuss via MS-TEAMS or use chat rooms via EMAS and study the literature on their own checking concepts that are not clear (50%) **Feedback:** Lecturers respond to discussions via MS-TEAMS or use chat rooms via EMAS (20%)	Students are competent: in determining the center of mass of the rigid body with the determined symmetry, deriving the equation of kinetic energy and inertia tensor	20%

14	Sub-CLO 7	Principle axis of the rigid body, the angular momentum of the rigid body, the Euler angle. **[Reference]** Chapter 11 required textbook	Asynchronous using recorded videos uploaded to youtube and EMAS UI (self-study & discussion forums) Synchronous via MS Teams	**Orientation:** Students can view files, watch videos or use chat rooms via EMAS (30%) **Exercise:** Students discuss via MS-TEAMS or use chat rooms via EMAS and study the literature on their own checking concepts that are not clear (50%) **Feedback:** Lecturers respond to discussions via MS-TEAMS or use chat rooms via EMAS (20%)	Students are competent: in analyzing the angular momentum and rotational motion of the rigid body with the angular formalism of Euler	

15	Sub-CLO 7	Euler's equation for the rigid body, symmetric top rotational motion. **[Reference]** Chapter 11 required textbook	Asynchronous using recorded videos uploaded to youtube and EMAS UI (self-study & discussion forums) Synchronous via MS Teams	**Orientation:** Students can view files, watch videos or use chat rooms via EMAS (30%) **Exercise:** Students discuss via MS-TEAMS or use chat rooms via EMAS and study the literature on their own checking concepts that are not clear (50%) **Feedback:** Lecturers respond to discussions via MS-TEAMS or use chat rooms via EMAS (20%)	Students are competent in deriving the equation of rotational motion or combination translation+rotation of rigid body by using Euler's equation	
16	**Final Exam**					

*) Wk: Week

ASSIGNMENT AND EXERCISE DESIGN

Week	Assignment Name	Sub-CLO	Assignment	Scope	Procedure	Deadline	Output
4	Individual Assignment 1	1, 2	Essay	Formalism of Newtonian for the motion of particle in 2D and 3D, gravity	Individual Homework	1 week	pdf file
5	Individual Assignment 2	3	Essay	Calculus of variation and Principle of Hamilton	Individual Homework	1 week	pdf file

7	Individual Assignment 3	4	Essay	Central force, orbital solution, orbital dynamics	Individual Homework	1 week	pdf file
9	Individual Assignment 4	5	Essay	Particle dynamics, collision in 2D and 3D	Individual Homework	1 week	pdf file
12	Individual Assignment 5	6	Essay	Coriolis force	Individual Homework	1 week	pdf file

15	Individual Assignment 6	7	Essay	Rigid body dynamics, Euler equation for rigid body	Individual Homework	1 week	pdf file

CRITERIA, INDICATOR & QUALITY OF GRADING (RESULTS OF LEARNING EVALUATION)
This section is written

Evaluation Type	Sub-CLO	Assessment Type	Frequency	Evaluation Quality (%)
Individual Assignment (HW)	1-7	Written test submitted via email	6x	40%
Midterm Exams	1-4	Written test submitted via email	1x	30%
Final Exams	5-7	Written test submitted via email	1x	30%
Total				**100%**

Grading Rubric:

This rubric is used as the guideline for assessing or grading the results of student performance. rubrics usually consist of assessment criteria that include dimensions/aspects that are assessed based on learning achievement indicators. This assessment rubric is useful for clarifying the basis 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.

Score	Grade	Quality
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—<55	D	1.00
<40	E	0.00

Grading Rubric

Criteria	**80~100**	**65~80**	**50~65**	**0~50**
Problem modeling	Students are competent in arranging the mathematical model by calculating the related laws of mechanics for and all the symmetries/parameters of the system are put into account	Students are competent in arranging the mathematical model by calculating the laws of mechanics that are related but has not considered the symmetries/parameters of the system	Students arranged the mathematical model but does not considered all the laws of mechanics that are related to the symmetries/parameters of the system	Students does not know what they have to do

Solution of equations of motion	Based on the constructed mathematical model, students are competent in finding the solutions to the equations of motion (using differential equations for most of the time) using mathematical techniques that have been studied in the Mathematical Physics course and determining the boundary/initial conditions according to the considered system.	Based on the constructed mathematical model, students are competent in finding the solution to the equations of motion (using differential equations for most of the time) by using mathematical techniques that have been studied in the Mathematical Physics course but have not applied the appropriate initial/limit.	Students make efforts to find the solution of equation of motions but incorrect	Students does not know what they have to do
Physical Interpretation	Students are competent in interpreting the obtained mathematical solution into a physical realization	Students are competent in interpreting the obtained mathematical solution into a physical realization, but not the interpretation is not precise	Students cannot interpret the obtained mathematical solution into a physical realization	Students are not competent in explaining the quantum properties