Annexe A: New/Revised Course Content in OBTL+ Format

Course Overview

Expected Implementation in Academic Year (New format)	AY2026-2027
Semester/Trimester/Others (specify approx. Start/End date)	Semester 1
Course Author * Faculty proposing/revising the course	Cheong Siew Ann
Course Author Email	cheongsa@ntu.edu.sg
Course Title	Analytical Mechanics
Course Code	PH2104
Academic Units	4
Contact Hours	52
Research Experience Components	Not Applicable

Course Requisites (if applicable)

Pre-requisites	(MH1803 and PH1104) OR (CY1601 and CY1602 and CY1308)
Co-requisites	
Pre-requisite to	
Mutually exclusive to	
Replacement course to	
Remarks (if any)	

Course Aims

This course aims to equip you with the basic concepts and problem solving skills in Analytical Mechanics. You will develop physical intuition and analytical skills which are important for studying physical systems and solve problems involving mechanical systems. This knowledge and skills lay the foundation for other physics courses such as quantum mechanics and photonics.

Course's Intended Learning Outcomes (ILOs)

Upon the successful completion of this course, you (student) would be able to:

ILO 1	Newtonian Mechanics (NM): analyse and solve problems involving motion with non-constant acceleration.
ILO 2	Newtonian Mechanics (NM) : analyse and solve problems involving oscillatory motions (such as simple harmonic oscillators in the presence of damping and driving force and coupled oscillators).
ILO 3	Newtonian Mechanics (NM) : apply conservation of momentum to solve physical problems.
ILO 4	Newtonian Mechanics (NM) : determine the properties of a system of particles such as centre of mass, moment of inertia and apply $\Sigma F \rightarrow_{ext} = dp \rightarrow /dt$ and $\Sigma \tau \rightarrow_{ext} = dL \rightarrow /dt$.
ILO 5	Non-inertial reference frames and rotating coordinate systems (NIRF) : analyse physics in a rotating frame of reference and discuss the origin of fictitious forces (such as Coriolis force and Centrifugal force).
ILO 6	Non-inertial reference frames and rotating coordinate systems (NIRF) : solve various physical problems in rotating frames (such as deflection of an object due to apparent gravity and motion of projectiles in rotating frames).
ILO 7	Lagrangian and Hamiltonian Mechanics (LHM) : identify and solve problems that can be represented as the minimisation of a functional.
ILO 8	Lagrangian and Hamiltonian Mechanics (LHM) : derive shapes of curves arising in physical problems (such as Brachistochrone and Catenoid) and give examples of where they occur in physics.
ILO 9	Lagrangian and Hamiltonian Mechanics (LHM) : write and use the Lagrangian to solve problems in classical physics (including systems with multiple objects) in generalized coordinates.
ILO 10	Lagrangian and Hamiltonian Mechanics (LHM) : derive equations of motion using Euler-Lagrange equations and use them to solve the dynamics of physical systems (including using Lagrange multipliers for constrained motion).
ILO 11	Lagrangian and Hamiltonian Mechanics (LHM) : discuss the importance of Noether's theorem in explaining the relation between symmetry and conserved quantities.
ILO 12	Lagrangian and Hamiltonian Mechanics (LHM) : use Hamilton's equations to define the motion of classical physics systems and sketch the phase diagrams of simple systems.
ILO 13	

	Lagrangian and Hamiltonian Mechanics (LHM) : use Lagrangian and Hamiltonian mechanics to analyse central force motions (such as deriving the geometric orbital equation and using it to determine shapes of planetary orbits, orbital changes due to impulse and predicting the existence of precession).
ILO 14	Rigid Body Rotation (RBR) : determine the inertia tensor of rigid bodies. derive Euler's equations for rotating rigid bodies and solve physical problems (such as precession of symmetric free tops and stability of rotation of asymmetric free tops about an axis.)

Course Content

Newtonian Mechanics (NM)

Equation of Motion with Non-constant Acceleration

Conservation theorems

Simple Harmonic Oscillators

Damped Oscillations

Driven Oscillations

Coupled Oscillators

Centre of Mass

Linear Momentum

Angular Momentum

Non-inertial reference frames and rotating coordinate systems (NIRF)

Rotating Coordinate Systems

Centrifugal and Coriolis Forces

Motion Relative to the Earth

Lagrangian and Hamiltonian Mechanics (LHM)

Euler's Equation

Lagrange's Equations of Motion in Generalized Coordinates

Lagrange's Equations with Undetermined Multipliers

Noether's Theorem

Phase Space Diagram

Hamilton's Equations of Motion

Geometric Orbit Equation

Keplerian Orbits

Precession

Rigid Body Rotation (RBR)

Inertia Tensor

Euler's Equations for Rigid Bodies

Precession of Symmetric Free Tops

Stability of Rigid-Body Rotations

Reading and References (if applicable)

1. Analytical Mechanics, 7th Edition, 2005, G. R. Fowles & G. L. Cassiday. (Brooks Cole). ISBN 978053440813.

2. Introduction to Classical Mechanics with problems and solutions, 2008, David Morin. (Cambridge). ISBN 978-0521876223.

3. Classical Mechanics, 3rd Edition, 2001, Herbert Goldstein, Charles P. Poole Jr. and John L. Safko. (Addison-Wesley). ISBN 978-0201657029.

NOTE: The above listing comprises the foundational readings for the course and more up-to-date relevant readings will be provided when they are available.

Planned Schedule

Week or Session	Topics or Themes	ILO	Delivery Mode	Activities	Readings
1	Motion with non-constant acceleration	NM 1	In-person	Lecture + Q&A	Chapter 1 lecture notes
2	Small oscillations and coupled oscillators	NM 2-4	In-person	Lecture + Q&A	Chapter 2 lecture notes
3	Non-inertia reference frames and rotating coordinate systems	NIRF 6	In-person	Lecture + Q&A	Chapter 3 lecture notes
4	Coriolis and centrifugal forces	NIRF 5	In-person	Lecture + Q&A	Chapter 4 lecture notes
5	Dynamics of systems of particles	NM and NIRF	In-person	Lecture + Q&A	Chapter 5 lecture note
6	Calculus of variations	LHM 7-8	In-person	Lecture + Q&A	Chapter 6 lecture notes
7	Lagrangian Dynamics	LHM 9	In-person	Lecture + Q&A	Chapter 6 lecture notes
8	Lagrangian Dynamics	LHM 9-11	In-person	Lecture + Q&A	Chapter 7 lecture notes
9	Hamiltonian Dynamics	LHM 12	In-person	Lecture + Q&A	Chapter 7 lecture notes
10	Hamiltonian Dynamics	LHM 12-13	In-person	Lecture + Q&A	Chapter 8 lecture notes
11	Central Forces and Planetary Motion	LHM 13	In-person	Lecture + Q&A	Chapter 8 lecture notes
12	Central Forces and Planetary Motion	LHM 13	In-person	Lecture + Q&A	Chapter 8 lecture notes
13	Rigid Body Rotation	RB 14-15	In-person	Lecture + Q&A	Chapter 9 lecture notes

Learning and Teaching Approach

Approach	How does this approach support you in achieving the learning outcomes?
Problem solving (tutorial and lecture)	Develop competence and perseverance in solving physics problems
Hands-on group activities (during tutorial)	Develop physical intuition and competence in solving real-life problems. Relate everyday phenomena to physics.
Peer Instruction (during lecture)	Develop communication skills and competence in physics. You are encouraged to discuss your answers to the Clickers questions so that you can learn from one another.

Assessment Structure

Assessment Components (includes both continuous and summative assessment)

No.	Component	ILO	Related PLO or Accreditation	Weightage	Description of Assessment Component	Team/Individual	Rubrics	Level of Understanding
1	Summative Assessment (EXAM): Final exam(Final Examination)	All		50		Individual	Analytic	Relational
2	Continuous Assessment (CA): Test/Quiz(Midterm Test 1)	1-6		15		Individual	Analytic	Relational
3	Continuous Assessment (CA): Test/Quiz(Midterm Test 2)	7-13		15		Individual	Analytic	Relational

No.	Component	ILO	Related PLO or Accreditation	Weightage	Description of Assessment Component	Team/Individual	Rubrics	Level of Understanding
4	Continuous Assessment (CA): Assignment(Learn the use of generative AI tools to deepen understanding of course materials)	All		10	During lectures, students will learn different generative AI tools to solve problems. They will also see the instructor use generative AI to create variations of problems or produce animations. For their assignments, they will then receive an original problem statement for which they must produce variations of, or to generate animations using generative AI.	Individual	Holistic	Relational

No.	Component	ILO	Related PLO or Accreditation	Weightage	Description of Assessment Component	Team/Individual	Rubrics	Level of Understanding
5	Continuous Assessment (CA): Class Participation(To encourage students to ask questions during lectures.)	All		10	Students will be rewarded for asking questions in lectures. Students will receive full marks for this component by asking questions in 80% of the lectures.	Individual	Holistic	Relational

Description of Assessment Components (if applicable)

*You would be expected to synthesise the physics concepts learnt in the course to propose scientifically valid approaches to given situations or problems.

Formative Feedback

You will receive formative feedback is given through discussion within tutorial lessons.

Feedback will also be provided for each problem set, where any particularly problematic areas will be identified.

Finally, feedback will be given after the midterm on the common mistakes and level of difficulty of the problems. Past exam questions and examiner's report are also made available for you.

NTU Graduate Attributes/Competency Mapping

This course intends to develop the following graduate attributes and competencies (maximum 5 most relevant)

Attributes/Competency	Level
Curiosity	Basic
Problem Solving	Basic
Sense Making	Advanced
Critical Thinking	Basic

Course Policy

Policy (Academic Integrity)

Good academic work depends on honesty and ethical behaviour. The quality of your work as a student relies on adhering to the principles of academic integrity and to the NTU Honour Code, a set of values shared by the whole university community. Truth, Trust and Justice are at the core of NTU's shared values. As a student, it is important that you recognize your responsibilities in understanding and applying the principles of academic integrity in all the work you do at NTU. Not knowing what is involved in maintaining academic integrity does not excuse academic dishonesty. You need to actively equip yourself with strategies to avoid all forms of academic dishonesty, including plagiarism, academic fraud, collusion and cheating. If you are uncertain of the definitions of any of these terms, you should go to the academic integrity website for more information. On the use of technological tools (such as Generative AI tools), different courses / assignments have different intended learning outcomes. Students should refer to the specific assignment instructions on their use and requirements and/or consult your instructors on how you can use these tools to help your learning. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

Policy (General)

For lecture participation, you are encouraged to ask questions if there are concepts you do not understand. Do not use AI to generate these questions, because our answers to these would not benefit you. You will have the opportunity to learn various generative AI tools for the assignment component. The use of AI is prohibited for the midterm tests and final exam components.

Policy (Absenteeism)

If you are unable to attend a class or test for medical or other reasons, you have to:

1. Send an email to the instructor regarding the absence and request for a replacement class and make-up mid-terms.
2. Submit the original Medical Certificate* or official letter of excuse to administrator.
3. Attend the assigned replacement class (subject to availability) and make-up mid-terms.

* The medical certificate mentioned above should be issued in Singapore by a medical practitioner registered with the Singapore Medical Association.

Policy (Others, if applicable)

Diversity and inclusion policy

Integrating a diverse set of experiences is important for a more comprehensive understanding of science.

It is our goal to create an inclusive and collaborative learning environment that supports a diversity of perspectives and learning experiences, and that honours your identities; including ethnicity, gender, socioeconomic status, sexual orientation, religion or ability.

To help accomplish this:

- If you are neuroatypical or neurodiverse, have dyslexia or ADHD (for example), or have a social anxiety disorder or social phobia;

- If you feel like your performance in the class is being impacted by your experiences outside of class;
- If something was said in class (by anyone, including the instructor) that made you feel uncomfortable;

Please speak to your teaching team, our school pastoral officer or a peer or senior (either in-person or via email) about how we can help facilitate your learning experience.

As a participant in course discussions, you should also strive to honour the diversity of your classmates. You can do this by: using preferred pronouns and names; being respectful of others opinions and actively making sure all voices are being heard; and refraining from the use of derogatory or demeaning speech or actions.

All members of the class are expected to adhere to the NTU anti-harassment policy. if you witness something that goes against this or have any other concerns, please speak to your instructors or a faculty member.