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 2
Course Author * Faculty proposing/revising the course	Lim Kyungtak
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Course Title	Plasma Astrophysics
Course Code	PH3412
Academic Units	3
Contact Hours	39
Research Experience Components	Not Applicable

Course Requisites (if applicable)

Pre-requisites	PH2102 & PH2401
Co-requisites	
Pre-requisite to	
Mutually exclusive to	
Replacement course to	
Remarks (if any)	

Course Aims

This course introduces you to the physics of plasmas in astrophysical and space environments. You will learn the core concepts needed to describe plasma behaviour, including plasma fundamentals, charged-particle motion, fluid and magnetohydrodynamic models, plasma waves, magnetic reconnection, selected instabilities, shocks, particle acceleration, dynamo action, and turbulence, together with a brief introduction to ionospheric and space-plasma applications. Intended for Year 3 and Year 4 physics students, the course provides a conceptual and problem-solving foundation for further study in astrophysics, plasma physics, and space science.

Course's Intended Learning Outcomes (ILOs)

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

ILO 1	Explain the defining characteristics of a plasma and estimate key plasma parameters relevant to astrophysical and space environments
ILO 2	Apply basic electromagnetic concepts and order-of-magnitude reasoning to simple plasma systems
ILO 3	Explain quasineutrality, Debye shielding, and plasma oscillations in astrophysical contexts
ILO 4	Analyse the motion of charged particles in electric and magnetic fields, including E×B, grad-B, and curvature drift motions
ILO 5	Apply gyrofrequency, Larmor radius, and the concept of adiabatic invariants to charged-particle motion
ILO 6	Describe the assumptions, usefulness, and limitations of fluid and magnetohydrodynamic descriptions of plasmas
ILO 7	Apply basic ideal MHD concepts, including magnetic pressure, magnetic tension, frozen-in flux, and magnetic induction, to large-scale astrophysical plasmas
ILO 8	Identify major plasma wave modes, including Alfvén, magnetosonic, Langmuir, and ion-acoustic waves, and interpret their basic physical properties
ILO 9	Explain magnetic reconnection and its role in energy conversion in solar and magnetospheric plasmas
ILO 10	Describe selected plasma instabilities and explain their relevance to astrophysical structures such as solar prominences, magnetotails, and jets
ILO 11	Explain the basic formation of collisionless shocks and their role in particle acceleration and non-thermal radiation
ILO 12	Describe the roles of dynamo action and turbulence in magnetic-field generation and energy transport in astrophysical plasmas
ILO 13	Relate plasma physics concepts to selected astrophysical and space-plasma applications, including the solar wind, interstellar medium, magnetospheres, and the ionosphere

Course Content

Basics and Plasma Fundamentals (BAS)

Plasma definition and characteristics
Quasineutrality and Debye shielding
Plasma frequency and basic plasma time scales
Key plasma parameters in astrophysical and space environments
Fluid and kinetic viewpoints of plasmas
Order-of-magnitude estimates for the solar wind, magnetosphere, and interstellar medium

Plasma Kinetics and Single-Particle Motion (KIN)

Lorentz force and charged-particle motion
Cyclotron motion, gyrofrequency, and Larmor radius
Guiding-centre approximation
E×B drift and selected magnetic drifts
Magnetic moment and magnetic mirroring at a conceptual level
Applications to charged-particle motion in space plasmas

Magnetohydrodynamics (MHD)

Fluid description of plasmas
Basic assumptions leading to the MHD model
Ideal MHD and the frozen-in condition
Magnetic pressure, magnetic tension, and force balance
Magnetic induction and magnetic Reynolds number
Applications to coronal loops, magnetotails, stellar winds, and astrophysical jets

Plasma Waves (WAV)

Alfvén waves
Magnetosonic waves
Langmuir and ion-acoustic waves
Basic wave speeds and dispersion properties
Introductory concepts of wave damping
Wave phenomena in the solar wind, corona, and magnetosphere

Astrophysical Processes (APP)

Magnetic reconnection and plasma energy conversion
Solar flares and magnetotail reconnection
Selected plasma instabilities in astrophysical systems
Collisionless shocks in heliospheric and astrophysical environments

Basic particle acceleration and non-thermal radiation
Applications to supernova remnants, pulsars, and astrophysical jets

Advanced Topics and Applications (ADV)

Dynamo action and magnetic-field generation in planets and stars
Basic concepts of plasma turbulence and energy cascades
Solar wind as a plasma laboratory
Applications to solar, magnetospheric, and interstellar plasmas
Brief introduction to ionosphere–magnetosphere coupling and space weather
Observational tools and missions for astrophysical and space plasmas

Reading and References (if applicable)

1. Russell M. Kulsrud, *Plasma Physics for Astrophysics*, Princeton University Press (2005). ISBN-13: 978-0691120737.
2. Arnab Rai Choudhuri, Astrophysics for Physicists, Cambridge University Press (2010). ISBN-13: 978-0521815536.
3. Francis F. Chen, Introduction to Plasma Physics and Controlled Fusion, Springer, 3rd ed. (2016). ISBN-13: 978-3319223087.
4. Karl Schindler, *Physics of Space Plasma Activity*, Cambridge University Press (2006). ISBN-13: 978-0521858977.

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	Plasma Fundamentals and Astrophysical Contexts	1-3	In-person	lecture on core concepts; worked examples; guided problem solving	Textbook and lecture notes
2	Charged-Particle Motion in Electric and Magnetic Fields	4-5	In-person	lecture on core concepts; worked examples; guided problem solving	Textbook and lecture notes
3	Fluid Description of Plasmas and the MHD Approximation	6	In-person	lecture on core concepts; worked examples; guided problem solving	Textbook and lecture notes
4	Ideal MHD: Magnetic Forces, Frozen-in Flux, and Induction	7	In-person	lecture on core concepts; worked examples; guided problem solving	Textbook and lecture notes
5	Plasma Waves in Astrophysical and Space Plasmas	8	In-person	lecture on core concepts; worked examples; guided problem solving	Textbook and lecture notes
6	Magnetic Reconnection and Energy Release	9	In-person	lecture on core concepts; worked examples; guided problem solving	Textbook and lecture notes
7	Selected Plasma Instabilities in Astrophysical Systems	10	In-person	lecture on core concepts; worked examples; guided problem solving	Textbook and lecture notes
8	Collisionless Shocks, Particle Acceleration, and Non-Thermal Radiation	11	In-person	lecture on core concepts; worked examples; guided problem solving	Textbook and lecture notes
9	Solar and Magnetospheric Plasma Applications	9-13	In-person	lecture on core concepts; worked examples; guided problem solving	Textbook and lecture notes

Week or Session	Topics or Themes	ILO	Delivery Mode	Activities	Readings
10	Dynamo Action and Magnetic-Field Generation	12	In-person	lecture on core concepts; worked examples; guided problem solving	Textbook and lecture notes
11	Plasma Turbulence and the Solar Wind	12-13	In-person	lecture on core concepts; worked examples; guided problem solving	Textbook and lecture notes
12	Interstellar, Stellar-Wind, and Jet Plasmas	13	In-person	lecture on core concepts; worked examples; guided problem solving	Textbook and lecture notes
13	Ionosphere, Space Weather, and Course Review	13	In-person	lecture on core concepts; worked examples; guided problem solving	Textbook and lecture notes

Learning and Teaching Approach

Approach	How does this approach support you in achieving the learning outcomes?
Lectures	Lectures provide the necessary content and practice of problem solving and discussion of conceptual understanding.
Tutorial	You review and discuss the main concepts from lectures with TAs by working through problems, while receiving timely feedback and guidance.
Homework	The homework comprises standard textbook practice questions that are covered during tutorial allowing for formative assessment and feedback.

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		55	The final examination assesses your overall understanding of the core concepts and problem-solving methods covered in the course. It evaluates both your conceptual understanding and your ability to apply plasma physics to astrophysical and space-plasma phenomena.	Individual	Analytic	Relational
2	Continuous Assessment (CA): Assignment(Homework 1)			10	Homework problem sets will be assigned to reinforce lecture concepts and provide practice in applying plasma-physics ideas to simplified astrophysical and space-plasma systems.	Individual	Analytic	Relational

No.	Component	ILO	Related PLO or Accreditation	Weightage	Description of Assessment Component	Team/Individual	Rubrics	Level of Understanding
3	Continuous Assessment (CA): Test/Quiz(Midterm test)			20	The midterm test will cover material from Weeks 1 through 6 or 7.	Individual	Analytic	Relational
4	Continuous Assessment (CA): Assignment(Homework 2)			10	Homework problem sets will be assigned to reinforce lecture concepts and provide practice in applying plasma-physics ideas to simplified astrophysical and space-plasma systems.	Individual	Analytic	Relational
5	Continuous Assessment (CA): Class Participation()			5	Participation in Wooclap sessions will be used to reinforce the concepts learned. To receive full marks, you are required to complete at least 9 of the 13 sessions.	Individual	Analytic	Relational

Description of Assessment Components (if applicable)

<u>Formative Feedback</u>

Formative feedback is provided weekly through assignment marking and tutorial lessons. A weekly TA meeting is also used to discuss the progress, pace, and difficulty level of the lectures. Formative feedback is given during clicker sessions in every lecture.

The midterm test also serves as a formative check of your understanding of the material covered. After the test, feedback is provided on common mistakes and on the overall difficulty level of the problems. Past exam questions and the examiner's report are also made available to you.

NTU Graduate Attributes/Competency Mapping

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

Attributes/Competency	Level
Adaptability	Intermediate
Communication	Intermediate
Creative Thinking	Intermediate
Curiosity	Intermediate
Problem Solving	Intermediate

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)

You are expected to complete all assigned readings, learning activities, and assessments, attend classes punctually, and submit all coursework by the stated deadlines. You are also responsible for keeping up with course announcements, instructions, and any updates related to the course. Active participation in class discussions, tutorials, and in-class learning activities is expected throughout the course.

Policy (Absenteeism)

In-class activities may contribute to your course grade, and unexcused absence from class may affect your participation grade. Absence will be considered valid only when supported by appropriate documentation, such as a medical certificate or an official excuse letter for participation in NTU-approved activities. For the midterm test, a make-up test may be arranged for students with valid documented absence, in accordance with University policy.

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.

PH3412 Plasma Astrophysics — Assessment Rubrics

1) Summative Assessment (EXAM): Final Exam (Final Examination) — 55%

A comprehensive examination assessing conceptual understanding and problem-solving ability across the full Plasma Astrophysics syllabus.

Criterion	Excellent	Good	Satisfactory	Limited
Conceptual understanding	Correct concepts consistently applied; demonstrates strong understanding	Mostly correct; minor misconceptions	Basic understanding but uneven	Major misconceptions / inappropriate concepts
Problem-solving process	Systematic, well-structured solutions; appropriate method selection	Mostly systematic; small gaps	Partially structured; steps not well connected	Disorganised; incorrect strategy
Mathematical accuracy	Correct derivations and final answers; correct units	Minor slips	Multiple errors affecting results	Frequent errors; largely incorrect
Clarity & communication	Clear, logical working; key steps shown; diagrams where helpful	Mostly clear	Some unclear or missing steps	Hard to follow / insufficient working

Partial credit is awarded for correct method and reasoning even if final numerical/algebraic answers are incomplete.

2) Continuous Assessment (CA): Assignment (Homework 1 & 2) — 10% each

A problem set on early-course topics assessing correct methods, reasoning, and clear presentation of solutions.

Criterion	Excellent	Good	Satisfactory	Limited
Method & setup	Correct approach and equations; assumptions/symmetry stated clearly	Mostly correct; minor omissions	Approach partly correct but incomplete	Wrong or unclear approach
Reasoning	Logical steps and justification; uses principles appropriately	Mostly logical	Limited justification	Weak/incorrect reasoning
Accuracy	Correct working and final answers; correct units	Minor errors	Several errors	Many errors; incorrect results
Presentation	Clear, readable, well-organised	Generally clear	Some unclear steps	Poorly presented / hard to follow

3) Continuous Assessment (CA): Test/Quiz (Midterm Test) — 25%

An in-class test on first-half material evaluating your understanding and ability to solve standard Plasma Astrophysics problems systematically.

Criterion	Excellent	Good	Satisfactory	Limited
Understanding	Applies correct concepts and laws; minimal misconceptions	Mostly correct; minor misconceptions	Basic recall; shaky application	Major misconceptions
Systematic problem-solving	Clear plan; correct strategy selection; coherent steps	Mostly systematic	Some relevant steps but not coherent	Incorrect strategy / disorganised
Accuracy	Correct derivations and answers; correct units	Minor slips	Multiple errors	Largely incorrect
Clarity	Work is readable; essential steps shown	Mostly clear	Some missing steps	Hard to follow

4) Continuous Assessment (CA): Class Participation (Wooclap) — 5%

Marks are awarded for consistent participation in in-class Wooclap concept checks, which provide immediate feedback and reinforce learning. Full marks are awarded for participation in at least 9 of the 13 Wooclap sessions.

You are considered to have participated in a session if you submit responses to the Wooclap questions during the lecture window. Accuracy is not graded.

Participation count (out of 13)	**Marks awarded for this component**
9–13 sessions	100%
7–8 sessions	80%
5–6 sessions	60%
3–4 sessions	40%
1–2 sessions	20%
0 sessions	0%