Spring 2024

PHYS 444 - 002: Fluid and Plasma Dynamics

Satoshi Inoue

COURSE OUTLINE **PHYSICS 444 (002)** **Spring 2024**

Class Schedule:

Class: Fluid and Plasma Dynamics
Day and Time: Tuesday and Thursday 10:00-11:20 pm
Room: Faculty Memorial Hall 305
Delivery Mode: Face-to-Face (Delivery of instruction is structured around in-person classroom meeting times. Instruction is delivered in person and students are expected to attend class).

General Information

Fluid dynamics is one of the most familiar physics in our lives, for example, the flows of rivers and wind, and its scope extends to the dynamics of the atmosphere and oceans. In space, it is filled with a world of intense plasma. This course offers a fundamental physics of fluid dynamics and plasma dynamics.
The goal of this class is to understand the fundamental equations of fluid dynamics, the ideal and non-ideal fluid dynamics and compressible fluid dynamics, and the behavior of plasma as fluid (Magnetohydrodynamics).
Since this course is for junior and senior undergraduate students, the course assumes basic physical mathematics (differential equations, vector analysis, matrix, Fourier analysis, etc.), classical mechanics, electromagnetism, and thermodynamics. As an important outcome, it is not just memorizing formulas, to make sure that the students understand the physical significance of the equations to be applied to research.

Instructor Information

Instructor: Satoshi Inoue
Center for Solar-Terrestrial Research (CSTR), New Jersey Institute of Technology (NJIT)
Office: 423C (Tiernan Hall)
Office Hour: Friday (3:00 pm-5:00 pm) in person or virtual, other times by appointment
Phone: 973-642-4059
E-Mail: Satoshi.Inoue@njit.edu
URL: http://inosato78.wixsite.com/inosatopage

1)Textbook : Lecture Files delivered in the class. As reference books,

1. The Physics of Fluids and Plasmas – An Introduction for Astrophysicists- by Armab Rai Choudhuri
2. Physics of Solar System Plasmas by Thomas E. Cravens
3. Computational Methods for Fluid Dynamics by Joel H. Ferziger, Milovan Peric, & Robert L. Street
4. Riemann Solvers and Numerical Methods for Fluid Dynamics by Eleuterio F. Toro

2) Lecture Quiz; The Quiz is given at the beginning of the class.

3) Homework; Homework will be assigned weekly.

4)Midterm and Final Exam; The Midterm exam will be asked from (neutral) fluid dynamics, and the Final exam will be asked from plasma physics. **Review the slides and problems provided in the class**.

Final Letter Grades: Here are the approximate weights to be used for calculating the composite score:

- **70%** for the midterm and final exams
  (Only final or midterm + final**, a** better grade will be considered.)
- **20%** for the lecture quiz and homework work
- **5%** for the attendance
- **5%** for the final report

The cutoff percentages for various letter grades will be:

Percentage	Letter Grade
> 80%	A
75 - 80	B+
70 – 75	B
65 - 70	C+
55 - 65	C
45- 55	D
< 45	F

<u>Final grades are not negotiable: A score of 79.99% is a B+, not an A.</u>

TOPIC	**TEXT STUDIES**	**NOTES**
Week 1 (1/16/24)	What is fluid? and fluid description.	Lagrange and Euler descriptions.
Week 1 (1/18/24)	Fundamental Equations of Fluid dynamics I.	Continuity equation (Mass conservation law).
Week 2 (1/30/24)	Fundamental Equations of Fluid dynamics I.	Equation of motion, and it's conservative description (Momentum conservation law).
Week 2 (2/1/24)	Fundamental Equations of Fluid dynamics I.	Energy equation I,
Week 3 (2/6/24)	Fundamental Equations of Fluid dynamics I.	Energy equation II
Week 3 (2/8/24)	Boltzmann equation.	Boltzmann equation
Week 4 (2/13/23)	Macroscopic description, Fundamental Equations of Fluid dynamics II.	Continuity equation, equation of motion.
Week 4 (2/15/23)	Macroscopic description, Fundamental Equations of Fluid dynamics II.	Energy equation
Week 5 (2/20/24)	Ideal fluid dynamics.	Incompressible fluid.
Week 5 (2/22/24)	Non-ideal fluid dynamics.	Viscosity, Navier-Stokes equation.
Week 6 (2/27/24)	Compressible fluid I.	Sound wave, Laval tube.
Week 6 (2/29/24)	Compressible fluid II.	Laval tube, shock wave.
Week 7 (3/5/24)	Compressible fluid III.	Shock wave, Solar wind.
Week 7 (3/7/24)	Introduction of Plasma physics.	Particle description in Plasmas.
Week 8 (3/19/24)	Midterm exam.	Fluid dynamics part will be asked.
Week 8 (3/21/24)	Introduction of magnetohydrodynamics (MHD) I.	Fundamental equations of MHD.

Week 9 (3/26/24)	Introduction of magnetohydrodynamics (MHD) II.	Fundamental equations of MHD.
Week 9 (3/28/24)	Fundamental of ideal-MHD I.	Frozen in, Magnetic Helicity, Taylor relaxation etc.
Week 10 (4/2/24)	Fundamental of ideal-MHD II.	Frozen in, Magnetic Helicity, Taylor relaxation etc.
Week 10 (4/4/24)	MHD equilibria.	Force-free field, MHD equilibria.
Week 11 (4/9/24)	MHD Wave.	Alfven wave, fast, and slow waves.
Week 11 (4/11/24)	Fluid instability & MHD instability I.	Rayleigh Taylor instability, Kelvin-Helmholtz instability
Week 12 (4/16/24)	Fluid instability & MHD instability II.	Parker instability, Magnetoconvection etc.
Week 12 (4/18/24)	Introduction of resistive MHD.	Magnetic reconnection,
Week 13 (4/23/24)	Fluid and Plasma Simulations I.	Fluid simulation using the differential method.
Week 13 (4/25/24)	Fluid and Plasma Simulations II.	Fluid simulation using the differential method and practice of simulation.
Week 14 (4/30/24)	Fluid and Plasma Simulations III.	Practice of simulation.