课程大纲
COURSE SYLLABUS

1.	课程代码/名称 **Course Code/Title**	MAE7001 多相流体力学 Multiphase Flow
2.	课程性质 **Compulsory/Elective**	专业选修 Major Elective Courses
3.	课程学分/学时 **Course Credit/Hours**	3/48
4.	授课语言 **Teaching Language**	英语 English
5.	授课教师 **Instructor(s)**	王连平教授、Brändle de Motta 教授 Professor Lian-Ping Wang and Professor Brändle de Motta
6.	是否面向本科生开放 **Open to undergraduates or not**	是 Yes
7.	先修要求 **Pre-requisites**	MAE303 流体力学 或者 MAE207 工程流体力学 Fluid Mechanics OR Engineering Fluid Mechanics

8. 教学目标
Course Objectives

本课程从三个方面处理两相流体力学：流体-固体和流体-流体界面的物理描述，含颗粒或液滴的稀释两相流，和密集两相流。 质量，动量和能量交换的局部和平均方程，无量纲参数，以及相关的工业应用。 两相流的数值方法。

This course treats two-phase flows from three perspectives: description at fluid-solid and fluid-fluid interfaces, dilute two-phase flow with particles and droplets, and dense two-phase flow. Local and averaging formulations of mass, momentum, and energy transfers and associated dimensionless parameters are discussed, along with relevant applications to industrial processes. The course also covers numerical methods for two-phase flows.

9. 教学方法
Teaching Methods

本课程主要通过教授讲课授课。大概每星期布置一次作业。另外，教授会给每位学生布置一篇论文，由学生研读后向全班作口头报告，并提交书面报告。本课程有一次期中考试和一次期末考试。

The course will meet with the usual lecture format. Homework sets will be assigned, graded and returned, roughly on weekly basis. Each student will be assigned an article to be reviewed. The student will make an oral presentation and will provide the instructor with a written review. There will be a midterm and a final exam.

10. 教学内容
Course Contents

Section 1	Introduction and objectives (2 credit hours): Overview of mathematical formulation of single-phase flow, two-phase flow vs single-phase flow, macroscopic vs microscopic description, dense vs dilute regime, dimensional analysis, industrial applications and natural phenomena involving two-phase flow.

Part I : Interface description

Section 2	Description of two-phase flow interface (1 credit hour): Local equations at the fluid-fluid and fluid-solid interfaces, curvature, Young-Laplace equation, contact angle.
Section 3	Analytical solutions (3 credit hours): Two-phase Poiseuille flow, Rayleigh-Taylor instability, bubbles stability.
Section 4	Application to spray atomization (3 credit hours): Orders of magnitude, stability of a droplet, Weber number, Eötvös number, spray primary and secondary break-up.
Section 5	Numerical approaches for two-phase interface treatment (3 credit hours): Volume of fluid approach, level-set approach, diffuse interface approach.
Part II: Dilute two-phase flow	
Section 6	Tools for spray analysis (1 credit hour): Lagrangian vs Eulerian, size probability density function, velocity probability density function, Sauter mean diameter.
Section 7	Droplet and particle transport equations (2 credit hours): Drag forces, secondary forces, collisions and coalescence, evaporation, mass and energy transfers.
Section 8	Turbulence interaction with droplets or particles (3 credit hours): Preferential concentration, energy transfer, turbulence modulation.
Section 9	Application to combustion chambers (3 credit hours): One droplet evaporation, one droplet combustion, spray combustion regimes, Chiu diagram.
Section 10	Numerical approaches for dilute two-phase flow (3 credit hours): Lagrangian approach, particles vs parcels. Eulerian approach, size discretization, sectional vs moments approaches.
Section 11	Midterm exam (3 credit hours): Evaluation of parts I and II. The exam will be graded and solutions will be provided.
Part III: Dense two-phase flow	
Section 12	Tools for dense-flows analysis (3 credit hours): Dimensionless parameters, Favre average, quantity of surface, drag coefficient for dense flow, models for contact collisions.
Section 13	Models for dense two-phase flow (3 credit hours): Theorems associated with volume averaging, derivation of volume-averaged equations for two-phase flow, constitutive relations for the dispersed phase.
Section 14	Application to two-phase heat exchanger (3 credit hours): Order of magnitude, boiling regimes, Nukiyama curve.
Section 15	Application to fluidized bed (3 credit hours): Solid-liquid vs solid-gas fluidized beds, fluidization regimes, Geldart classification, Richardson-Zaki relation.
Section 16	Numerical approaches for dense two-phase flow (3 credit hours): One-fluid vs two-fluid approaches, Eulerian-Lagrangian Spray Atomization (ELSA) approach, closure equations.
Section 17	Article presentation (3 credit hours +/- depending on the number of students): Each student makes a 10-minute conference-like presentation. They will present the results of a paper that will be distributed at the beginning of the semester. Papers will be different for each student and be selected by the instructors. This session provides the

		class the state-of-the-art knowledge of two-phase flows.
	Section 18	Review (3 credit hours): New applications of two-phase flow, current research topics in two-phase flow, from two-phase flow to multiphase flow. Overview of important results of the course and open questions.

11. 课程考核
Course Assessment

（①考核形式 Form of examination；②.分数构成 grading policy；③如面向本科生开放，请注明区分内容。 If the course is open to undergraduates, please indicate the difference.）

1.no final exam

2. 出勤 **Attendance** **10%**
平时作业 **Assignments** **20%**
期中考试 **Mid-Term Test** **20%**
期末考试 **Final Exam.** **30%**
期末报告 **Final Presentation** **20%**

3.There is no difference between undergraduate and graduate students.

12. 教材及其它参考资料
Textbook and Supplementary Readings

- Crowe, C. T., J. D. Schwarzkopf, M. Sommerfeld, and T. Yutaka (2012). *Multiphase Flows with Droplets and Particles*. 2nd ed. Boca Raton: CRC Press.
- Collier, J. G., and Thome, J. R. (1994). *Convective boiling and condensation*. Clarendon Press.

P.K. Kundu, I.M. Cohen, and D.R. Dowling (2016). *Fluid Mechanics*, 6th edition, Elsevier.