课程大纲
COURSE SYLLABUS

1.	**课程代码/名称** **Course Code/Title**	MAE5029 稀薄气体动力学：理论和应用 Rarefied gas dynamics: theory and applications
2.	**课程性质** **Compulsory/Elective**	选修 Elective
3.	**课程学分/学时** **Course Credit/Hours**	3/64
4.	**授课语言** **Teaching Language**	English
5.	**授课教师** **Instructor(s)**	Lei Wu
6.	**先修要求** **Pre-requisites**	无

7. 教学目标
Course Objectives

本课程为力学与航空航天工程系(或计算数学)研究生专业选修课,主要讲述稀薄气体动力学的基本理论和数值方法。知识点包括：传统 Navier-Stokes 方程的不适用性、稀薄气体动力学的广泛应用、Boltzmann 方程的推导以及与 Navier-Stokes 方程的关系、简化分子动理论模型的建立。课堂教学以理论推导为主，同时实践部分提供相关计算机数值模拟程序，以帮助学生加深对稀薄气体动力学等问题的理解。

This is an elective course for master and PhD students in the Department of Mechanics and Aerospace Engineering (or computational mathematics) dedicated to the introduction of fundamental theory and numerical methods in rarefied gas dynamics. Topics covered include the breakdown of Navier-Stokes equations, wide range applications of rarefied gas dynamics, derivation of the Boltzmann equation and its relation to the Navier-Stokes equations, and the kinetic modelling of monatomic and polyatomic gas. In addition to the theoretical deduction in classroom teaching, this course will provide several numerical simulation codes for the students to better understand the rarefied gas dynamics.

8. 教学方法
Teaching Methods

Regular lectures and research projects

9. 教学内容
Course Contents

Section 1	Introduction (2 hour) • Ideal gas: length scale, mean free path, pressure and energy • Estimation of shear viscosity and thermal conductivity • Breakdown of Navier-Stokes equations • Knudsen number and route to non-equilibrium
Section 2	Boltzmann equation (6 hours) • Phase-space and velocity distribution function; velocity moments • Derivation of the Boltzmann equation; H-theorem • Gas-surface interaction

	Section 3	Numerical method for the Boltzmann equation (8 hours) • Direct simulation of Monte Carlo • Fast spectral method; conventional iterative scheme • Shock waves; Fourier/Couette flow
	Section 4	Fluid-dynamics equations (4 hours) • Hilbert expansion • Chapman-Enskog expansion • Moment equations • Accuracy of fluid-dynamics equations: numerical examples
	Section 5	Kinetic modelling of monatomic gas (6 hours) • Gross-Jackson construction • BGK/ES-BGK/Shakhov models • Numerical comparisons
	Section 6	Kinetic modelling of polyatomic gas (8 hours) • Origin of bulk viscosity and its elusive behavior • Wang-Chang and Uhlenbeck equation; Hanson-Morse, Rykov, ESBGK, Wu models • Uncertainty in thermal conductivity and its quantification • Numerical examples: Shock wave; Rayleigh-Brillouin scattering
	Section 7	General synthetic iterative scheme (8 hours) • Unified gas-kinetic scheme • GSIS: fast convergence and asymptotic preserving • Numerical examples： velocity-slip and temperature-jump coefficients, etc. • GSIS vs upscaling methods: similarities and differences?
	Section 8	Dense gas and multiphase flow (6 hours) • Enskog-Vlasov equation for non-ideal gas • Non-equilibrium phase transition: evaporation/condensation coefficients • comparisons with lattice Boltzmann method
10.	课程考核 **Course Assessment**	
	请在此注明： ①考查/考试： 考查 ②分数构成。 出勤 Attendance 10% 课程项目 Projects 40% 期末报告 Final Presentation 50%	
11.	教材及其它参考资料 **Textbook and Supplementary Readings**	
	"Kinetic modelling and multiscale simulation of rarefied gas dynamics" by Lei Wu. "Macroscopic transport equations for rarefied gas flows" by Henning Struchtrup.	