NATIONAL TSING HUA UNIVERSITY
DEPARTMENT OF POWER MECHANICAL ENGINEERING
2014 Fall Semester

Course No.:	10310 PME 510200
Course Title:	**Multiscale Transport (多尺度傳輸)**
	(Fluid, Molecule and Quantum Particle Flows)
Hours/Week:	T6 T7 T8
Classroom:	工一館 R 209
Teacher:	Prof. Che-Wun Hong (洪哲文教授)

Contents:

(1) Introduction to Multi-scale Transport

1.1 Development of Multi-scale Transport in Physics
1.2 Classical Physics and Modern Physics
1.3 Macroscopic and Microscopic Models
1.4 Micro Flow Examples
1.5 Macro Flow Development
1.6 Kinetic and Transport Properties of Fluids
1.7 General Boundary Conditions

(2) Macro Flow Models (The Navier-Stokes Equation)

2.1 Fundamental Equations
2.2 Conservation of Mass (Continuity Equations)
2.3 Conservation of Momentum (Navier-Stoke Equations)
2.4 Conservation of Energy (1st Law of Thermodynamics)
2.5 Summary of the Basic Equations
2.6 Examples of Boundary Conditions
2.7 Orthogonal Coordinate System
2.8 Mathematical Characters of the Basic Equations
2.9 Dimensional Analysis and Dynamic Similarity
2.10 Summary of the Basic Equations in CFD
2.11 Control Volume Formulations
2.12 Integral Form of the Generic Conservation Equation

(3) Analytical Solutions of the Continuum Flow

3.1 Classification of Solutions
3.2 Couette Flows
3.3 Poiseuille Flow through Ducts
3.4 The Circular Pipe: Hagen-Poiseuille Flow

3.5 Combined Couette-Poiseuille Flow between Plates
3.6 Noncircular Ducts
3.7 Temperature Distribution in Fully Developed Duct Flow
3.8 Thermal Entrance: The Graetz Problem
3.9 Creeping Flow (Low Reynolds Number Flow)

(4) Numerical Solutions of the N-S Equations (CFD)

4.1 Differential Form of the N-S Equations
4.2 Integral Form of the N-S Equations
4.3 Mathematical Characters of the Basic Equations
4.4 Finite Difference Methods for Elliptic Problems
4.5 Finite Difference Methods for Parabolic Problems
4.6 Finite Difference Methods for Hyperbolic Problems
4.7 Finite Difference Methods for CFD
4.8 Finite Volume Methods for CFD
4.9 Finite Element Methods for CFD

(5) Micro Flow Models (The Boltzmann Equation)

5.1 Basic Equations for Micro Flows
5.2 Rarefied Gas Flows
5.3 Basic Kinetic Theory
5.4 The Boltzmann Equation
5.5 The Moment of the Boltzmann Equation
5.6 Conservation Equations
5.7 Exact Solution to the Boltzmann Equation
5.8 Micro Flows and Macro Flows

(6) Numerical Solutions of the Lattice Boltzmann Model (LBM)

6.1 From the Boltzmann Equation to the Lattice Boltzmann Equation
6.2 BGK Lattice Boltzmann Model in 3D and 2D
6.3 Entropy and Equilibrium Distribution
6.4 Flow Chart of the BGK LBM Algorithm
6.5 Boundary Conditions
6.6 More Boundary Conditions

(7) Nano Flows (Molecular Dynamics and Monte Carlo)

7.1 Macro, Micro, and Nano Scales
7.2 Intermolecular Potential Models
7.3 Periodical Boundary Condition
7.4 Initialization
7.5 Equilibration
7.6 Fluid and Solid Mechanics

7.7 Radial Distribution Function
7.8 General Monte Carlo Methods

(8) Quantum Flows (The Schrödinger Equation)

8.1 Development of Quantum Mechanics
8.2 The Born Interpretation
8.3 Classical Wave Equations
8.4 The 1-D Simple Harmonic Oscillator
8.5 Wavefunction for a Free Particle
8.6 Wavefunctions in the Presence of Potential Forces
8.7 Numerical Method for the Schrödinger Equation
8.8 The Particle in a Box
8.9 The Finite Square Well
8.10 The Square Potential Barrier
8.11 Electron, Photon and Phonon Statistics
8.12 Unified Quantum Fluid Dynamics and Quantum LBM

(9) Computational Quantum Mechanics (CQM)←depends on time left

Lecture Notes: Supplement notes provided by PDF before each lecture

References:

(1) "Viscous Fluid Flow" F.M. White, 3rd Ed., McGraw-Hill, 2006 (N-S Eq.)
(2) "Computational Methods for Fluid Dynamics", J.H. Ferziger, M. Peric, Springer, 2002. (CFD)
(3) "Molecular Gas Dynamics and the Direct Simulation of Gas Flows", G.A. Bird, Clarendon Press, 1994. (DSMC+MD)
(4) "Lattice-Gas Cellular Automata and Lattice Boltzmann Models- An Introduction", D. A. Wolf-Gladrow, Springer, 2005 (LBM)
(5) "Modern Physics", 3rd Ed., R.A. Serway, C.J. Moses, C.A. Moyer, Thomson, 2005 (Schrodinger Eq.)

Grades:

Exercises (20%)
Midterm Exam (40%), close book
Final Report and Presentation (40%)