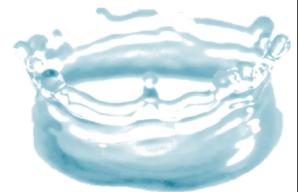


# Introduction to Fluid Mechanics (FGEE024812)



Prof. Dariusz Wanatowski  
万岱历 教授  
Pro-Dean of the SWJTU-Leeds Joint School  
西南交通大学-利兹学院 副院长  
Email: [dwanat@gmail.com](mailto:dwanat@gmail.com)  
Office: X30530



1

## Introducing Fluid Mechanics teaching team...

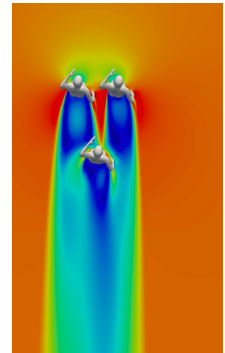


2

## Prof. Dariusz WANATOWSKI

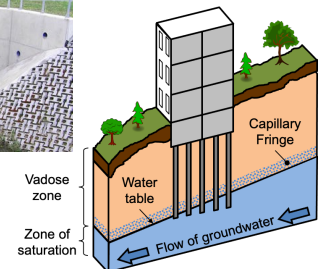
### Education and Work Experience:

1999, MSc Highway Eng., Poznan University of Technology, Poland  
 2005, PhD Geotechnical Eng., NTU Singapore  
 2005-06, Post-doctoral Researcher, NTU Singapore  
 2006-13, University of Nottingham, UK  
 2007-08, ARUP, Nottingham (Geotechnical Consultant, part-time)  
 2013-16, University of Nottingham, Ningbo, China  
 2016-now, University of Leeds and SWJTU-Leeds Joint School



### Expertise

Advanced Soil Mechanics  
 Geotechnical Engineering  
 Ground Improvement  
 Slope Stability

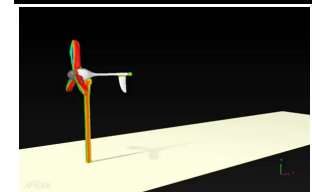
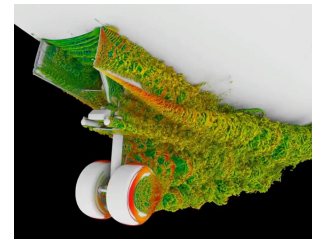
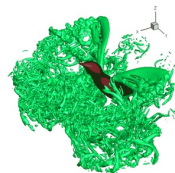


3

## Dr. Jamie F. TOWNSEND

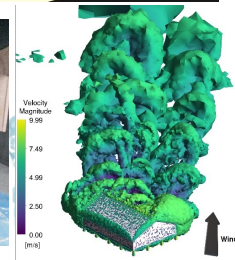
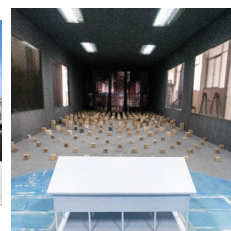
### Education and Work Experience:

2015, BSc (Hons) Mathematics, Plymouth University, UK  
 2016, MSc Computational Fluid Dynamics, Cranfield University, UK  
 2019-20, Visiting Research Fellow, Nagoya University, Japan  
 2020, PhD Aerospace, Cranfield University, UK  
 2020-21, Postdoctoral Research Fellow, Cranfield University, UK  
 2021-now, Postdoctoral Researcher, Southwest Jiaotong University, China



### Expertise

Computational Fluid Dynamics  
 Wind Engineering  
 Wind Tunnel Testing  
 Numerical Methods



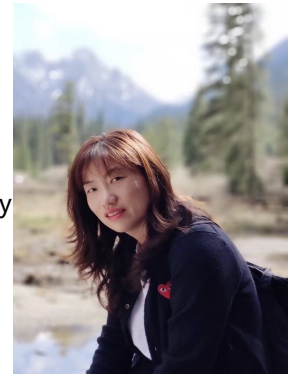
4

## Dr. Chen Yu

### Education and Work Experience:

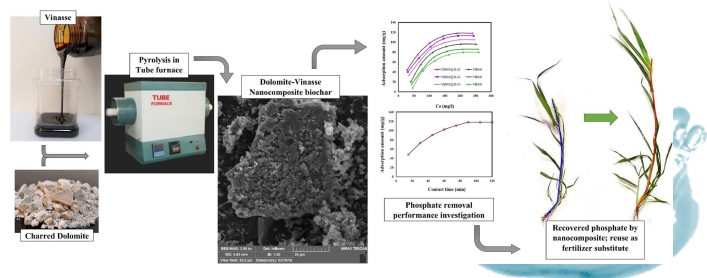
2002, Undergraduate degree of Civil Engineering, Southwest Jiaotong University  
 2005, Master's degree of Environmental Engineering, Southwest Jiaotong University  
 2015, Ph.D. for Municipal Engineering, Southwest Jiaotong University

Since 2005, Senior Engineer for Environmental Engineering  
 in the Faculty of Geosciences and Environmental Engineering  
 at the Southwest Jiaotong University



### Expertise

Sewage treatment engineering design  
 Phosphorus removal and recovery  
 Heavy metal pollution control  
 Solid waste recycling application



5

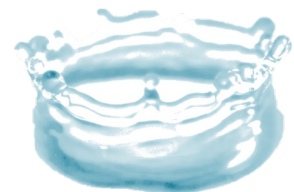
## Overview

**Class time:** Monday 9:50–12:15 (Weeks 1-17, Final Exam in Week 18)

**Classroom:** X4247

**Course description:** This course is intended to introduce the **fundamentals** of fluid mechanics to undergraduate environmental engineering students.

**Prerequisites:** ENSC 2113 (**Statics**), MATH 2153 (**Mathematics**).



6

## Course Objectives

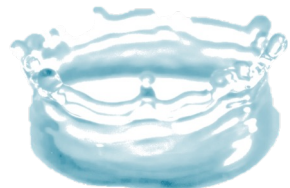
- ❑ Introduce students to the fundamental theories and principles of fluid mechanics.
- ❑ Develop practical problem-solving skills in fluid mechanics including the use of: equations of state, hydrostatic equation, conservation of mass (continuity), conservation of energy, conservation of linear momentum, fluid friction equations for laminar flow, turbulent conduit flow and open channel flow, external flow lift and drag equations, pump performance curves, and isentropic flow applied to nozzles.
- ❑ Consolidate and enhance basic knowledge of mathematics, physics and mechanics, and cultivate the ability to analyze and solve practical problems in environmental engineering.



7

## Learning Objectives

- ❑ Fluid Mechanics as a professional basic course for environmental engineering majors, is a bridge connecting early basic courses and subsequent professional courses.
- ❑ Through the study of this course, students will master the basic properties of fluids, the laws of fluid stillness and motion, the interaction between fluids and boundaries, open channel flow, pipe flow, weir flow, and have basic skills in fluid calculations (hydraulic calculations) for solving relevant fluid mechanics problems in the environmental engineering major.

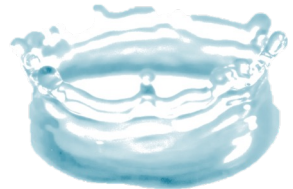


8

## Learning Outcomes

Upon completion of this course students will

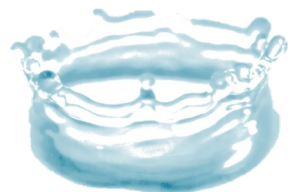
- ❑ **Master** fundamental theories and principles of fluid mechanics.
- ❑ **Develop** practical problem-solving skills in fluid mechanics.
- ❑ **Consolidate** and enhance their knowledge of mathematics, physics and fluid mechanics relevant to environmental engineering.



9

## Why is this important to you?

Fluid mechanics is **ubiquitous in the field of environmental engineering** as the majority of environmental heat and pollutant transport processes are driven by fluid flows including dominant processes that control heat, mass, and pollutant transport in the environment.



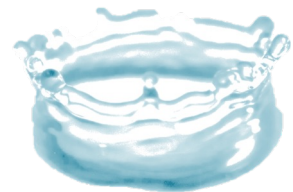
10

## Why is this important to you?

A number of environmental, geotechnical and structural engineering problems are intimately linked to fluid mechanics.

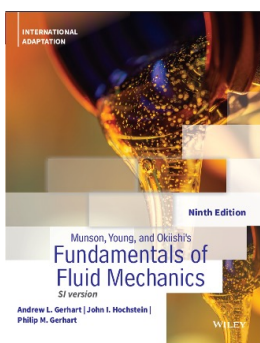
Examples include

- ☐ the synergy of fluid principles in air pollution control
- ☐ water and wastewater treatment
- ☐ groundwater management and control
- ☐ and the construction of dams and bridges



11

## Required Textbook >>> YOU MUST HAVE IT !!!

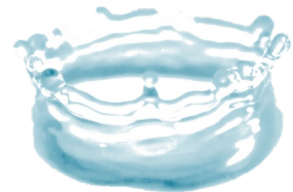


### Fundamentals of Fluid Mechanics

Ninth Edition

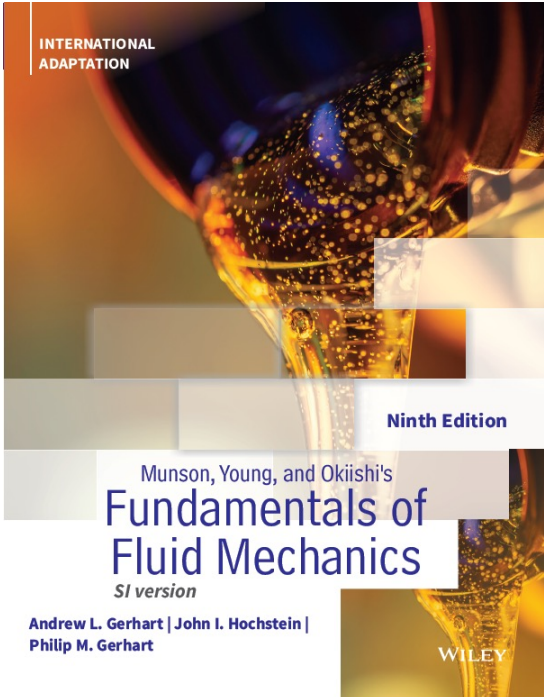
Munson • Young • Okiishi

Philip M. Gerhart • Andrew I. Gerhart • John I. Hochstein

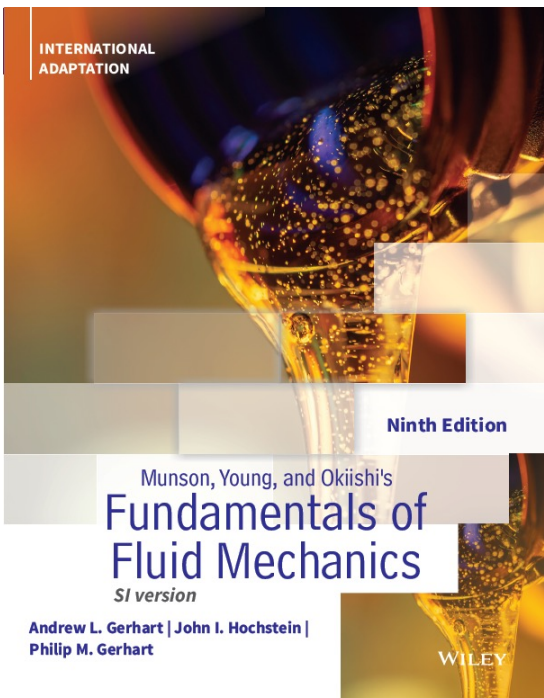


12



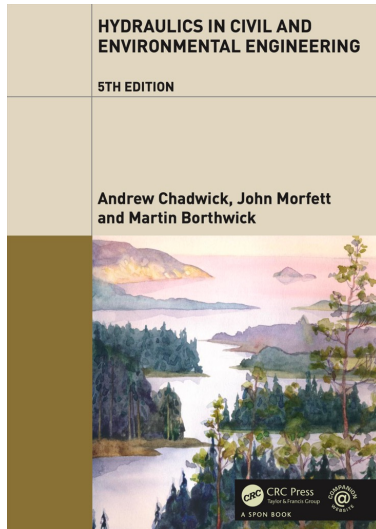
		Contents	
<b>1 Introduction</b> 1		<b>2.12 Pressure Variation in a Fluid with Rigid-Body Motion</b> 70	
<b>Learning Objectives</b> 1		<b>2.12.1 Linear Motion</b> 70	
<b>1.1 Some Characteristics of Fluids</b> 3		<b>2.12.2 Rigid-Body Rotation</b> 72	
<b>1.2 Dimensions, Dimensional Homogeneity, and Units</b> 4		<b>Chapter Summary and Study Guide</b> 74	
<b>1.3 Analysis of Fluid Behavior</b> 12		<b>References</b> 75	
<b>1.4 Measures of Fluid Mass and Weight</b> 12		<b>3 Elementary Fluid Dynamics—The Bernoulli Equation</b> 76	
<b>1.4.1 Density</b> 12		<b>Learning Objectives</b> 76	
<b>1.4.2 Specific Weight</b> 14		<b>3.1 Newton's Second Law</b> 76	
<b>1.4.3 Specific Gravity</b> 14		<b>3.2 <math>F = ma</math> along a Streamline</b> 79	
<b>1.5 Ideal Gas Law</b> 14		<b>3.3 <math>F = ma</math> Normal to a Streamline</b> 83	
<b>1.6 Viscosity</b> 17		<b>3.4 Physical Interpretations and Alternate Forms of the Bernoulli Equation</b> 85	
<b>1.7 Compressibility of Fluids</b> 23		<b>3.5 Static, Stagnation, Dynamic, and Total Pressure</b> 88	
<b>1.7.1 Bulk Modulus</b> 23		<b>3.6 Examples of Use of the Bernoulli Equation</b> 93	
<b>1.7.2 Compression and Expansion of Gases</b> 24		<b>3.6.1 Free Jets</b> 93	
<b>1.7.3 Speed of Sound</b> 25		<b>3.6.2 Confined Flows</b> 96	
<b>1.8 Vapor Pressure</b> 26		<b>3.6.3 Flowrate Measurement</b> 102	
<b>1.9 Surface Tension</b> 27		<b>3.7 The Energy Line and the Hydraulic Grade Line</b> 106	
<b>1.10 A Brief Look Back in History</b> 30		<b>3.8 Restrictions on Use of the Bernoulli Equation</b> 109	
<b>Chapter Summary and Study Guide</b> 32		<b>3.8.1 Compressibility Effects</b> 109	
<b>References</b> 34		<b>3.8.2 Unsteady Effects</b> 110	
<b>2 Fluid Statics</b> 35		<b>3.8.3 Rotational Effects</b> 111	
<b>Learning Objectives</b> 35		<b>3.8.4 Other Restrictions</b> 112	
<b>2.1 Pressure at a Point</b> 35		<b>Chapter Summary and Study Guide</b> 113	
<b>2.2 Basic Equation for Pressure Field</b> 36		<b>References</b> 114	
<b>2.3 Pressure Variation in a Fluid at Rest</b> 38		<b>4 Fluid Kinematics</b> 115	
<b>2.3.1 Incompressible Fluid</b> 39		<b>Learning Objectives</b> 115	
<b>2.3.2 Compressible Fluid</b> 42		<b>4.1 The Velocity Field</b> 115	
<b>2.4 Standard Atmosphere</b> 43		<b>4.1.1 Eulerian and Lagrangian Flow Descriptions</b> 118	
<b>2.5 Measurement of Pressure</b> 45		<b>4.1.2 One-, Two-, and Three-Dimensional Flows</b> 119	
<b>2.6 Manometry</b> 47		<b>4.1.3 Steady and Unsteady Flows</b> 120	
<b>2.6.1 Piezometer Tube</b> 47		<b>4.1.4 Streamlines, Streaklines, and Pathlines</b> 120	
<b>2.6.2 U-Tube Manometer</b> 48		<b>4.2 The Acceleration Field</b> 124	
<b>2.6.3 Inclined-Tube Manometer</b> 50		<b>4.2.1 Acceleration and the Material Derivative</b> 124	
<b>2.7 Mechanical and Electronic Pressure-Measuring Devices</b> 51		<b>4.2.2 Unsteady Effects</b> 127	
<b>2.8 Hydrostatic Force on a Plane Surface</b> 54			
<b>2.9 Pressure Prism</b> 60			
<b>2.10 Hydrostatic Force on a Curved Surface</b> 63			
<b>2.11 Buoyancy, Flotation, and Stability</b> 65			
<b>2.11.1 Archimedes' Principle</b> 65			
<b>2.11.2 Stability</b> 68			

13

		xx CONTENTS	
<b>10.2 Surface Waves</b> 439		<b>11.9.3 Rayleigh Lines, Fanno Lines, and Normal Shocks</b> 534	
<b>10.2.1 Wave Speed</b> 439		<b>11.10 Analogy Between Compressible and Open-Channel Flow</b> 535	
<b>10.2.2 Froude Number Effects</b> 442		<b>11.11 Two-Dimensional Supersonic Flow</b> 536	
<b>10.3 Energy Considerations</b> 444		<b>11.12 Effects of Compressibility in External Flow</b> 538	
<b>10.3.1 Energy Balance</b> 444		<b>Chapter Summary and Study Guide</b> 541	
<b>10.3.2 Specific Energy</b> 445		<b>References</b> 544	
<b>10.4 Uniform Flow</b> 448		<b>12 Turbomachines</b> 545	
<b>10.4.1 Uniform Flow Approximations</b> 448		<b>Learning Objectives</b> 545	
<b>10.4.2 The Chezy and Manning Equations</b> 449		<b>12.1 Introduction</b> 546	
<b>10.4.3 Uniform Flow Examples</b> 451		<b>12.2 Basic Energy Considerations</b> 547	
<b>10.5 Gradually Varied Flow</b> 457		<b>12.3 Angular Momentum Considerations</b> 551	
<b>10.6 Rapidly Varied Flow</b> 458		<b>12.4 The Centrifugal Pump</b> 553	
<b>10.6.1 The Hydraulic Jump</b> 460		<b>12.4.1 Theoretical Considerations</b> 554	
<b>10.6.2 Sharp-Crested Weirs</b> 464		<b>12.4.2 Pump Performance Characteristics</b> 558	
<b>10.6.3 Broad-Crested Weirs</b> 467		<b>12.4.3 Net Positive Suction Head (NPSH)</b> 560	
<b>10.6.4 Underflow (Sluice) Gates</b> 470		<b>12.4.4 System Characteristics, Pump-System Matching, and Pump Selection</b> 562	
<b>Chapter Summary and Study Guide</b> 471		<b>12.5 Dimensionless Parameters and Similarity Laws</b> 566	
<b>References</b> 472		<b>12.5.1 Special Pump-Scaling Laws</b> 568	
<b>11 Compressible Flow</b> 473		<b>12.5.2 Specific Speed</b> 569	
<b>Learning Objectives</b> 473		<b>12.5.3 Suction Specific Speed</b> 570	
<b>11.1 Ideal Gas Thermodynamics</b> 474		<b>12.6 Axial-Flow and Mixed-Flow Pumps</b> 571	
<b>11.2 Stagnation Properties</b> 479		<b>12.7 Fans</b> 573	
<b>11.3 Mach Number and Speed of Sound</b> 480		<b>12.8 Turbines</b> 574	
<b>11.4 Compressible Flow Regimes</b> 485		<b>12.8.1 Impulse Turbines</b> 575	
<b>11.5 Shock Waves</b> 489		<b>12.8.2 Reaction Turbines</b> 582	
<b>11.5.1 Normal Shock</b> 489		<b>12.9 Compressible Flow Turbomachines</b> 585	
<b>11.6 Isentropic Flow</b> 495		<b>12.9.1 Compressors</b> 585	
<b>11.6.1 Steady Isentropic Flow of an Ideal Gas</b> 495		<b>12.9.2 Compressible Flow Turbines</b> 589	
<b>11.6.2 Incompressible Flow and the Bernoulli Equation</b> 498		<b>Chapter Summary and Study Guide</b> 591	
<b>11.6.3 The Critical State</b> 500		<b>References</b> 593	
<b>11.7 One-Dimensional Flow in a Variable Area Duct</b> 500		<b>APPENDIX A Computational Fluid Dynamics</b> 594	
<b>11.7.1 General Considerations</b> 501		<b>APPENDIX B Physical Properties of Fluids</b> 613	
<b>11.7.2 Isentropic Flow of an Ideal Gas with Area Change</b> 504		<b>APPENDIX C Properties of the U.S. Standard Atmosphere</b> 618	
<b>11.7.3 Operation of a Converging Nozzle</b> 510		<b>APPENDIX D Compressible Flow Functions for an Ideal Gas with <math>k = 1.4</math></b> 620	
<b>11.7.4 Operation of a Converging-Diverging Nozzle</b> 512		<b>APPENDIX E Comprehensive Table of Conversion Factors</b> 628	
<b>11.8 Constant-Area Duct Flow with Friction</b> 516		<b>QUESTIONS AND PROBLEMS</b> SP-1	
<b>11.8.1 Preliminary Consideration: Comparison with Incompressible Duct Flow</b> 516		<b>INDEX</b> I-1	
<b>11.8.2 The Fanno Line</b> 517			
<b>11.8.3 Adiabatic Frictional Flow (Fanno Flow) of an Ideal Gas</b> 520			
<b>11.9 Frictionless Flow in a Constant-Area Duct with Heating or Cooling</b> 528			
<b>11.9.1 The Rayleigh Line</b> 528			
<b>11.9.2 Frictionless Flow of an Ideal Gas with Heating or Cooling (Rayleigh Flow)</b> 531			

14

## Recommended Textbook > YOU DON'T HAVE TO HAVE IT



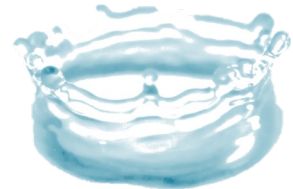
### Contents

Preface  
Acknowledgements  
Short History of Hydraulics  
Introductory Notes  
Principal Symbols

#### PART I PRINCIPLES AND BASIC APPLICATIONS

1	Hydrostatics	1
2	Principles of Fluid Flow	3
27	3 Behaviour of Real Fluids	27
73	4 Flow in Pipes and Closed Conduits	73
101	5 Open Channel Flow	101
135	6 Pressure Surge in Pipelines	135
197	7 Hydraulic Machines	197
215		215

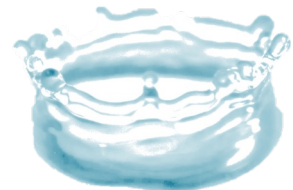
8	Wave Theory	229
9	Sediment Transport	301
10	Flood Hydrology	329
11	Dimensional Analysis and the Theory of Physical Models	389
	PART II ASPECTS OF HYDRAULIC ENGINEERING	419
12	Pipeline Systems	421
13	Hydraulic Structures	447
14	Computational Hydraulics	495
15	River and Canal Engineering	535
16	Coastal Engineering	569
17	Postscript	607
	Appendix A: Moments of Area	609
	Index	613



15

## Tentative Teaching Calendar

Week	Date and time	Teaching Contents	Instructor	Teaching time		Notes
				Lecture	Practice	
1	26/2/24 (9:50-12:15)	Ch 1: Introduction	DW	3	0	-----
2	4/3/24 (9:50-12:15)	Ch 2: Fluid Statics (part 1)	JT	2	1	-----
3	11/3/24 (9:50-12:15)	Ch 2: Fluid Statics (part 2)	JT	2	1	-----
4	18/3/24 (9:50-12:15)	Ch 3: Elementary Fluid Dynamics – The Bernoulli Equation	DW	2	1	-----
5	25/3/24 (9:50-12:15)	Ch 4: Fluid Kinematics	DW	2	1	<b>Homework 1 (Ch: 1-4)</b>
6	1/4/24 (9:50-12:15)	Ch 5: Finite control Volume Analysis	JT	2	1	-----
7	8/4/24 (9:50-12:15)	Ch 6: Differential Analysis of Fluid Flow (part 1)	DW	2	1	-----



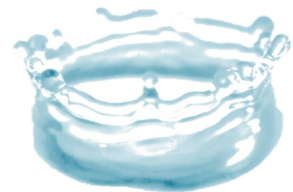
16



8	15/4/24 (9:50-12:15)	Ch 6: Differential Analysis of Fluid Flow (part 2)	DW	2	1	-----
9	22/4/24 (9:50-12:15)	Ch 7: Dimensional Analysis, Similitude, and Modeling (part 1)	DW	2	1	-----
10	29/4/24 (9:50-12:15)	Ch 7: Dimensional Analysis, Similitude, and Modeling (part 2)	DW	2	1	<b>Mid-term Exam (Ch 1-7)</b>
11	6/5/24 (9:50-12:15)	Ch 8: Viscous Flow in Pipes	JT	2	1	-----
12	13/5/24 (9:50-12:15)	Ch 9: Flow Over Immersed Bodies	DW	2	1	-----
13	20/5/24 (9:50-12:15)	Ch 10: Open-Channel Flow	JT	2	1	-----
14	27/5/24 (9:50-12:15)	Ch 11: Compressible Flow (part 1)	JT	2	1	<b>Homework 2 (Ch: 8-11)</b>
15	3/6/24 (9:50-12:15)	Ch 11: Compressible Flow (part 2)	JT	2	1	-----
16	10/6/24	<b>NO CLASS (Dragon Boat Festival)</b>				
17	17/6/24 (9:50-12:15)	Ch 12 Turbomachines	JT	2	1	-----
18	24/6/24 (10:00-12:00)	<b>Final exam</b> (details to be confirmed later)				

**Note:** For details of Chapters please refer to *Munson et al., 'Fundamentals of Fluid Mechanics', 8th Edition, Wiley & Sons.*

Attendance is **COMPULSORY**. It is necessary to be successful in this course. If you cannot attend any lectures due to illness or other reasons beyond your control, please inform the instructors and teaching assistant in advance.



17

## Assessment

### Grading Policy:

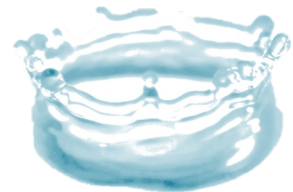
Homework 1	10% (week 5)
Mid-term Exam	25% (week 10)
Homework 2	10% (week 14)
Final Exam	55% (week 18)

### Grade Scale:

A: 85 - 100%
B: 75 - 84%
C: 60 - 74%
F: 0 - 59%



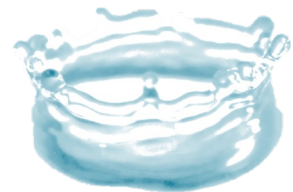
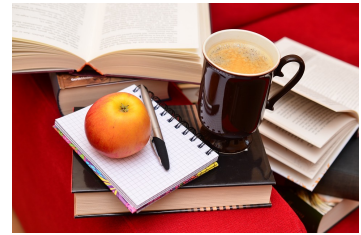
**Academic Misconduct:** In this course, all the assignments including homework and exams should represent your individual effort, unless explicitly stated in the assignment. You may talk with other students and tutors about your assignments, but you should work through the computations individually and submit your own answers.



18

## How to do well in the course?

- ☐ Come prepared to the class.
- ☐ Participate actively in the class.
- ☐ Get familiar with a new vocabulary, if necessary...
- ☐ Practice example problems from the textbook.
- ☐ Discuss your learning problems with teaching team.  
Please let us know your problem in advance.
- ☐ Solve homework problems yourself and do not worry too much about homework grades.
- ☐ Revise well before your exams.



19

## Questions



20