Course Profile

Degree Program:

☐ECE-Electrical & Computer Engineering
* ME-Mechanical Engineering
☐General Courses for Both ECE & ME Degree Programs

Course Name: Biofluid Mechanics
Course Code: VM xxx
Course Credits: 4
Course Category: ☐ Required * Elective

Terms Offered:
☐Fall __________
☐Spring ________________ (YYYY-YYYY)
√ Summer_2021-2022_ (YYYY-YYYY)

Course Pre/Co-requisites:
Mathematic courses: calculus, differential calculus, vector analysis
Mechanics courses: theoretical mechanics (dynamics), thermodynamics, fluid mechanics

Course objectives:
1. Understand the basics of haemodynamics, aspiration, flying and swimming of animals at both high and low Reynolds number environment, and fluid flows in plants.
2. Understand required theories and analysis methods for biofluid problems.
3. From some typical application examples to have a training to extract the essential physics from biological phenomena.

Reference books (no textbook for this course)
Fluid Mechanics, 5th edition, by Pijush K. Kundu, Ira M. Cohen and David R. Dowling, Academic Press, 2012

Applied Biofluid Mechanics, by Lee Waite and Jerry Fine, McGraw-Hill Education; 1st edition (June 21, 2007), ISBN: 978-0071472173

Biofluid Mechanics: The Human Circulation, by Krishnan B. Chandran, Stanley E. Rittgers and Ajit P. Yoganathan, CRC Press; 2nd edition (February 24, 2012), ISBN: 978-1439845165

Biomechanics: Circulation, by Y. C. Fung.

Low Reynolds number hydrodynamics by John Happel and Howard Brenner

Principles of Animal Locomotion by R. McNeill Alexander, Princeton University Press (March 19, 2006)

The Fluid Dynamics of Cell Motility by Eric Lauga, Cambridge University Press; 1st edition (November 5, 2020)

Animal Locomotion by Graham Taylor, Michael S. Triantafyllou, and Cameron Tropea, Springer-Verlag Berlin and Heidelberg GmbH & Co. KG

Classes:

Instructors: (Email, Office hours and Office Room No. should be included)
Zijie Qu （屈子杰）
Office: Room 517, JI Building
E-mail: zijie.qu@sjtu.edu.cn

Grading Policy:
- Homework: weighting factor 45%
- One medium-term exam: grading weighting factor 15%
- One course project: grading weighting factor 15%
- One final exam; grading weighting factor: 25%

Academic Integrity: (Any types of honor code regulations like class rules, homework policy, exam rules or project collaboration policy could be defined here)

It is very necessary to show up in the class. Homework assignments need to finish independently and submit on time. Frequent discussions and exchanges with the instructor or TAs are strongly encouraged. To make a fair judgment of learning, strict rules related to homework assignments and exams need to be formulated without exception. Any honor code violation behavior (e.g. plagiarism) must be recorded with corresponding penalty.

Please attach your course description and detailed teaching schedules here:

Chapter 1: Introduction to Fluid Mechanics (brief review of the VM320)

1. A brief review of the key concepts in fluid mechanics including stress and strain, surface tension,

viscosity, laminar and turbulent flows, etc.

2. A brief review of the laws/equations/analytical approaches: conservation laws, Bernoulli's equations, boundary layer, etc. and how these fundamentals are related to biological systems.

Chapter 2: The Circulatory System in Human Body

1. Heart as a pump, the nature of blood and the nature of blood vessels. An introduction to non-Newtonian effect including viscoelasticity, the shear-dependent viscosity, etc. and how these non-Newtonian effects are measured and modelled.

2. Modelling of flows in blood vessels. Hagen-Poiseuille flow and the Fahraeus-Lindqvist effect, effect of developing flow (the idea of entrance length), effect of tube wall elasticity on Poiseuille flow, Laminar Flow of a Casson Fluid in a Rigid Walled Tube, Pulmonary Circulation, etc.

3. Respiration. Mechanics of breathing, work of breathing (a P-V diagram), airway resistance, gas exchange and transport (the idea of diffusion), etc.

Chapter 3: Swimming Flying and Animal Collective Motion

1. Swimming at different Reynolds numbers. Swimming strategies adopted by animals at different length scales (from macroscopic to microscopic). Swimming at high Re number: a review of vorticity and vortex. A lift-based propulsion – how dolphin swims? forces on bodies with constant velocity, the effect of turbulent flows on fish. Swimming at low Re number: from N-S equation to Stokes Equation, the analytical solution of Stokes Equation (Stokeslet), the features of low Re number flow (time reversibility, linearity, etc.), Resistance Force Theory.

2. Flying. Flying at different scales - the birds and the bees, 3-D steady flight, gliding, soaring, steady horizontal flight, why cannot we fly? the clap and fling mechanism for insect flight. (Kelvin's circulation theorem)

3. Animal collective motion (seminar style lectures): bacterial swarming, active matter self-assembling, fish schooling, bird flocking.

Chapter 4: Introduction to Fluid Mechanics of Plants

Xylem flow, phloem flow, water uptake and transport in vascular plants

Chapter 5: The Measurement Techniques and Modelling

1. Pressure Measurement. Indirect pressure measurement – Doppler ultrasound, direct pressure measurement: intravascular, extravascular, electrical analog of the catheter measuring systems, etc.

2. Flow measurement. Indicator dilution method, Fick technique for measuring cardiac output, thermodilution, electromagnetic flowmeter, continuous wave ultrasonic flowmeters.