Elasticity

Scope:

As a part of a broader field known as continuum mechanics, theory of elasticity analyzes the kinematics and the mechanical behavior of solid matter modeled as a continuous mass rather than as discrete particles. It plays a paramount role in both understanding natural phenomena and guiding technical designs of structures.

The present course introduces students to Theory of Elasticity and some of its most updated applications in research, and the course contains two parts:
1. The first part discusses mathematical and physical principles of Theory of Elasticity using an array of classical examples, such as compression, deflection and torsion of a beam.
2. In conjunction with a concurrent course taught by Prof. Hu Dan: Theory of Fluid Mechanics, the second part of the course introduces a set of problems at the frontier of current scientific research. Through these advanced topics, students can acquire the ability of applying theory to real-world problems and can develop basic understandings of a wide range of phenomena, such as how things break, why our skin wrinkles, how bacteria move, why wet hairs stick together, and how to walk on water.

Instructor:

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Office Hours: Tuesday: 16:00-18:00 and Thursday: 15:00-17:00.

Grading:

The grade will be determined on the basis of regular homework assignments and a final project. Instructor will provide a list of possible final projects. However, with the instructor’s approval, students can also choose any subject, related to elasticity and/or fluid mechanics, of their own interest for the final project.

Required Textbooks and Materials:

Textbooks:
   中文翻译版：连续介质力学初级教程 / 冯元桢 著，葛东云，陆明万 译 / 清华大学出版社

影印版：固体力学引论——清华大学国际著名力学图书.影印版系列

Other books and research articles:
Course Content:

Basic theory of elasticity:

In the first part (18 classes), we cover basic theory of elasticity and its application to classical examples.

1.1. Deformation, stress tensor and basic equations:
   Classes: 2 classes
   References: Chaper 3-5, 12 in [1].

1.2. Formulation and solution strategies:
   Classes: 3 classes
   References: Chaper 5 in [2].

1.3. Strain energy and related Principles
   Classes: 3 classes
   References: Chaper 6 in [2].

1.4. Two-Dimensional Formulation and solution
   Classes: 4 classes
   References: Chaper 7-8 in [2].

1.5. Torsion, and flexure of elastic cylinders
   Classes: 4 classes
   References: Chaper 9 in [2].

1.6. Three dimensional problem and contact mechanics
   Classes: 2 classes
   References: Chaper 4 in [3].

Advanced topics in elasticity and fluid mechanics:

The second part of the course (10 classes) will be taught in conjunction with a concurrent course given by Prof. Hu Dan: Theory of Fluid Mechanics. Motivation behind this combined approach is two-fold. First, many techniques and methods are equally applicable in both elasticity and fluid mechanics (section 2.1-2.3). Second, there are a wide range of phenomena involving interactions between solids and fluids; understanding of these phenomena requires knowledge from both courses (section 2.4).

2.1. Complex variables method and its applications in fluid mechanics and elasticity:
   Classes: 2 classes in Elasticity + 2 classes in Fluid mechanics
   → Introduction to complex variables method
      References: Chaper 6 in [4]; Chaper 10 in [2].
   → Application in fluid mechanics: flow around 2D aerodynamic wing. (How planes fly?)
      References: Chaper 6, 15 in [4].
   → Application in elasticity: 2D fracture mechanics (How things break?)
      References: Chaper 10 [2]; Review papers [5, 6].

2.2. Wave dynamics in Fluid mechanics and elasticity
   Classes: 2 classes in Elasticity + 2 classes in Fluid mechanics
   → Basics of waves: phase velocity, group velocity, dispersion relation and other basics.
      References: Chaper 7 in [4]; introduction in [7].
   → Waves in fluids: sound wave, surface and internal gravity waves and shock wave.
      References: Chaper 7, 14 in [4].
   → Waves in solids: waves in a string; waves in infinite media.
      References: Chaper 1, 5 in [7].
2.3. Instability and Pattern formation

Classes: 2 classes in Elasticity + 2 classes in Fluid mechanics

→ Introduction to instability and pattern formation
  References: Introduction in [8]; Chaper 12 in [4].
→ Rayleigh-Bernard instability in heated fluids
  References: Chaper 12 in [4].
→ Elastic instabilities: buckling and wrinkling instabilities. (Why our skin wrinkles? Why flowers have wavy edge?)
  References: Papers [9, 10, 11, 12].

2.4. Fluid-solid interaction

Classes: 4 classes in Elasticity + 4 classes in Fluid mechanics

→ Life and motion at low Reynolds number (How bacteria, sperm, and algae move in viscous fluid?)
  References: Papers [13, 14].
→ Vortex dynamics and Fluid-solid interaction at medium Reynolds number (How fish and bird move by generating vortices? Why falling leaves tumble and rotate?)
  References: book [15, 16]; Papers [17, 18, 19].
→ Elasto-capillary dynamics (How to walk on water? How to make a capillary origami? Why wet hairs stick together?)
  References: Papers [20, 21, 22, 23, 24].
→ Filaments and membranes in a viscous fluid
  References: Papers [25].


