# MECH 570C: Fluid-Structure Interaction

**Course Overview:** The course aims at the continuum theory and variational formulations of fluid-structure interaction (FSI). The course begins with a review of the motion kinematics and the balance laws for the fluid and solid continua. In the first part, various prominent continuum FSI theories such as arbitrary Lagrangian-Eulerian, immersed/embedded interface, fictitious domain, fully Eulerian (e.g., phase field and level set) will be systematically covered. In the second part, variational formulation and finite element implementation of the prominent FSI techniques and strategies will be taught with the aid of coding examples and educational software tools. Finally, an overview of emerging reduced-order and data-driven modeling techniques for dynamical FSI problems will be provided together with various engineering applications.

**Rationale for introducing this module**: Practicing mechanical engineers in aerospace, biomedical, civil and marine/offshore industries must possess knowledge of fluid-structure interaction. Next generation aircraft, space vehicles, turbomachinery, offshore marine/systems and bridges need a detailed understanding of fluid-elastic effect and its implications on the design of flexible structures for high-performance, structural reliability and efficiency. The objectives of this course are to provide students with the fundamental understanding of fluid-elastic principles and concepts which are required to (i) enable physical insight into the behavior of a broad class of fluid-elastic instability; and (ii) to understand and model industrial-strength coupled fluid-structure mechanics in a systematic and rigorous manner.

**Course Coordinator:** Rajeev Jaiman,
Office: ICICS 171, Email: rjaiman@mech.ubc.ca

**Prerequisites:** Students should normally have taken an engineering or physics course in fluid and structural mechanics at the undergraduate level and be registered as graduate students.

**Recommended Textbooks:**

Jaiman, R.K. and Joshi, V. “Computational Mechanics of Fluid-Structure Interaction”, Springer-Verlag 2021.

**Learning Outcomes or Objectives:**
After completing Mech 570C, you will be able to:

- Familiarity with common types of coupled fluid-structure and aero/hydroelastic systems.
- Identification of common non-dimensional numbers and coupled physical effects in fluid-structure systems.

- Understanding of critical mathematical concepts and continuum theory of fluid-structure interaction.
- Various computational techniques for solving nonlinear FSI problems.
- Working knowledge of vortex-induced vibration, galloping, limit cycle oscillations, flutter and other flow-induced vibration phenomena.
- Overview of advanced computational techniques, variational formulations, reduced-order models and machine learning techniques.

**Lecture Topics and Organization:**

1. Introduction to fluid-structure interaction
2. Equilibrium, Kinematics and Balance Laws
3. Continuum Mechanics Aspects of FSI
4. Variational and Stabilized Finite Element Methods
5. Fluid-Structure Interaction: Variational Formulation
6. Monolithic and Partitioned FSI Formulations
7. Immersed/Embedded FSI Techniques
8. Fully Eulerian FSI Techniques
9. Advanced Topics and Applications

**Course Format and Evaluation:**

The students will meet twice weekly for 1½-2 hour lectures. These will be supplemented by a number of discussion sessions and student presentations.

Evaluation will comprise: Problem Set= 20%, Coding Project= 30%, Course Project=30%, Final Exam=20%

Every student will get to lead a paper discussion from a reading list of relevant literature in FSI. Along with presenting the technical content of the paper, students will be encouraged to turn the paper discussion into an interactive event by posing questions to the class, presenting their perspective on the strengths and limitations of prior work and their applicability to other application domains, and identifying promising ideas for future research. Students will also submit peer-evaluations of the presentation and their individual reviews of the paper after every discussion session.

Based on the lectures, students will undertake a project to have hands-on experience of theory and analysis of fluid-structure interaction. A report on the project work will be prepared for evaluation. Students are highly encouraged to choose a problem from an application domain they are most familiar with where they can leverage their unique perspective on the scientific background of the FSI problem, although a list of sample projects will be provided by the instructor along with regular project pitches by students. Students will get to work in groups to identify and formulate a research problem, apply, explore the FSI problem, and demonstrate the real-world effectiveness of FSI research. Project deliverables include project proposals, midterm presentation, final presentation, and final report. All project activities starting from idea generation to report preparation will be facilitated through online peer discussions coordinated by the instructor.

Grading breakdown of course project: paper presentation (15%), project proposal (10%), mid-term project review (15%), final project report and presentation (30%), paper reviews and course participation (30%)

## Learning Activities and Modes of Teaching:

Slides presentations; lectures and tutorials; out-of-lecture-hour consultations; course notes; computational demonstrations; relevant web-links; compulsory and supplementary reading list.

This is a project-based course that will use a mix of learning activities ranging from theoretical problem solving, coding assignments and projects. These activities are designed to provide an overview of the foundations and recent trends in FSI research, as well as to inculcate skills necessary to pursue research in FSI.

## Academic Integrity

The academic enterprise is founded on honesty, civility, and integrity. As members of this enterprise, all students are expected to know, understand, and follow the codes of conduct regarding academic integrity. At the most basic level, this means submitting only original work done by you and acknowledging all sources of information or ideas and attributing them to others as required. This also means you should not cheat, copy, or mislead others about what is your work. Violations of academic integrity (i.e., misconduct) lead to the breakdown of the academic enterprise, and therefore serious consequences arise and harsh sanctions are imposed. For example, incidences of plagiarism or cheating may result in a mark of zero on the assignment or exam and more serious consequences may apply if the matter is referred to the President's Advisory Committee on Student Discipline. Careful records are kept in order to monitor and prevent recurrences. All individual work that you submit should be completed by you and submitted by you.

A more detailed description of academic integrity, including the University's policies and procedures, may be found in the Academic Calendar at http://www.calendar.ubc.ca/vancouver/index.cfm?tree=3,286,0,0#15620