

**Math 790, Independent Study in the Concentration of  
Computational Mathematics  
Numerical Methodology for Fluid-Structure  
Interaction (FSI) Problems  
Fall 2016  
(8/29/2016-12/9/2016)**

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**COURSE DESCRIPTION:** This independent study topic aims at the modeling and advanced numerical methodology studies for fluid-structure interaction (FSI) problems. Incompressible fluid flow modeled by the dynamic Navier-Stokes equations in Eulerian description, and compressible elastic structure modeled by the dynamic mechanical equation in Lagrangian description together with the structural constitutive laws are coupled through some appropriately proposed boundary conditions on the moving interfaces of fluid and structure, forming a monolithic model system of FSI. In terms of mesh conformity through the fluid-structure interfaces, numerical methodologies to tackle FSI model comprise the arbitrary Lagrangian-Eulerian (ALE) method (conforming mesh), fictitious domain method (nonconforming mesh), and full Eulerian method with phase field model, level set model (single mesh), and etc. Mixed finite element method, upwind-finite volume method, Galerkin-least-square method and streamline diffusion method are the main numerical techniques for discretizing and stabilizing the induced saddle-point type weak formulations of FSI problems. The other classification of numerical methodology for FSI simulation is based upon the solution strategy for the derived discretization scheme, termed as partitioned method if fluid and structure equation are separately computed within an alternating iteration cycle and communicate with each other through the interface transmission condition, and as monolithic method if both fluid and structure equations are computed together within a saddle-point system where the interface conditions are built into the discretization spaces. Depending on the academic progress and practical situation of the graduate students, some of the above numerical methods will be appropriately chosen to investigate for their independent studies.

Reference materials and lecture notes will be distributed in the class.

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**COURSE PROJECT:** The graduate students will complete an intensive study of the FSI problems on the aspects of both modeling and numerical methodology, where, modeling study includes Navier-Stokes equations, constitutive relations for the linear elasticity problem, and conservation laws. Numerical study comprises certain types of numerical techniques in terms of different classification, such as arbitrary Lagrangian-Eulerian method and fictitious domain method, or monolithic method and partitioned method. Graduate students will critically examine these advanced numerical methods and their applications to a general FSI model. Special attention will be given to the algorithm design and analysis of the efficient and robust numerical technique in order to overcome some particular but significant situations existing in FSI applications, e.g., when the structure is deforming, rotating and translating, at the same time, interacting with the surrounding fluid flow.

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**COURSE OBJECTIVES:** Upon completion of this course, the graduate student will:

- Develop and pursue a unique study question through substantial, legitimate research that fosters focus and flexibility.
  - Maintain a research note documenting work and sources.
  - Gain a thorough understanding of the topic through investigation and discussion of modeling and numerical studies, such as conservation laws, monolithic FSI model and the associated scientific and engineering computing.
  - Contribute original scholarship of the topic, including developing a source code and summary of previous work.
  - Prepare an article based on work for submission to a conference or journal.
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**INSTRUCTIONAL METHODS AND LEARNING:** This is an independent study utilizing extensive readings, intensive research, and experiential learning. Questions, observations and computer programming are strongly required.

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**COURSE PARTICIPATION AND ATTENDANCE:** Expect to meet weekly with the advisor for discussion, advising, and constructive criticism. However, the graduate student is personally responsible for the development and progress of the project. Meetings can be held semiweekly if necessary or desired. Contact via email and phone is encouraged.

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**GRADE DETERMINATION:** Regular attendance and participation in meetings is required and essential for success. If special circumstances arise, the graduate student must contact the advisor as soon as possible.

The final grade is determined by the graduate student's adherence and development of a research note, a paper of the findings and analysis (10-15 pages), and attendance and participation including regular progress of the project. Grades are ultimately at the discretion of the advisor.

Paper = 50%

Research note = 30%

Attendance and participation = 20%

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**ACADEMIC INTEGRITY:**

Academic integrity is the pursuit of scholarly activity in an open, honest and responsible manner. Academic integrity is a basic guiding principle for all academic activity at University of Nevada, Las Vegas, and all members of the University community are expected to act in accordance with this principle. Consistent with this expectation, the University's Code of Conduct states that all students should act with personal integrity, respect other students' dignity, rights and property, and help create and maintain an environment in which all can succeed through the fruits of their efforts.

Academic integrity includes a commitment not to engage in or tolerate acts of falsification, misrepresentation or deception. Such acts of dishonesty violate the fundamental ethical principles of the University community and compromise the worth of work completed by others. Based on the University's [Student Academic Misconduct Policy](#), a range of academic sanctions may be taken against a student who engages in academic dishonesty.

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**DISCLAIMER:** The advisor reserves the right to make verbal or written changes to the syllabus at any time. All changes and exceptions are at the advisor's discretion.

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## UNLV POLICIES

**Academic Misconduct:** Academic integrity is a legitimate concern for every member of the campus community; all share in upholding the fundamental values of honesty, trust, respect, fairness, responsibility and professionalism. By choosing to join the UNLV community, students accept the expectations of the Student Academic Misconduct Policy and are encouraged when faced with choices to always take the ethical path. Students enrolling in UNLV assume the obligation to conduct themselves in a manner compatible with UNLV's function as an educational institution. An example of academic misconduct is plagiarism. Plagiarism is using the words or ideas of another, from the Internet or any source, without proper citation of the sources. See the Student Academic Misconduct Policy (approved December 9, 2005) located at: <https://www.unlv.edu/studentconduct/student-conduct>.

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**Copyright:** The University requires all members of the University Community to familiarize themselves **with** and to follow copyright and fair use requirements. **You are individually and solely responsible for violations of copyright and fair use laws. The university will neither protect nor defend you nor assume any responsibility for employee or student violations of fair use laws.** Violations of copyright laws could subject you to federal and state civil penalties and criminal liability, as well as disciplinary action under University policies. Additional information can be found at: <http://www.unlv.edu/provost/copyright>.

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**Disability Resource Center (DRC):** The UNLV Disability Resource Center (SSC-A 143, <http://drc.unlv.edu/>, 702-895-0866) provides resources for students with disabilities. If you feel that you have a disability, please make an appointment with a Disabilities Specialist at the DRC to discuss what options may be available to you. If you are registered with the UNLV Disability Resource Center, bring your Academic Accommodation Plan from the DRC to the instructor during office hours so that you may work together to develop strategies for implementing the accommodations to meet both your needs and the requirements of the course. Any information you provide is private and will be treated as such. To maintain the confidentiality of your request, please do not approach the instructor in front of others to discuss your accommodation needs.

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**Religious Holidays Policy:** Any student missing class quizzes, examinations, or any other class or lab work because of observance of religious holidays shall be given an opportunity during that semester to make up missed work. The make-up will apply to the religious holiday absence only.

It shall be the responsibility of the student to notify the instructor within the first 14 calendar days of the course for fall and spring courses (excepting modular courses), or within the first 7 calendar days of the course for summer and modular courses, of his or her intention to participate in religious holidays which do not fall on state holidays or periods of class recess. For additional information, please visit: <http://catalog.unlv.edu/content.php?catoid=6&navoid=531>.

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**Transparency in Learning and Teaching:** The University encourages application of the transparency method of constructing assignments for student success. Please see these two links for further information:

<https://www.unlv.edu/provost/teachingandlearning>

<https://www.unlv.edu/provost/transparency>

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**Incomplete Grades:** The grade of I—Incomplete—can be granted when a student has satisfactorily completed three-fourths of course work for that semester/session but for reason(s) beyond the student’s control, and acceptable to the instructor, cannot complete the last part of the course, and the instructor believes that the student can finish the course without repeating it. The incomplete work must be made up before the end of the following regular semester for undergraduate courses. Graduate students receiving “I” grades in 500-, 600-, or 700-level courses have up to one calendar year to complete the work, at the discretion of the instructor. If course requirements are not completed within the time indicated, a grade of F will be recorded and the GPA will be adjusted accordingly. Students who are fulfilling an Incomplete do not register for the course but make individual arrangements with the instructor who assigned the I grade.

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**Tutoring and Coaching** — The Academic Success Center (ASC) provides tutoring, academic success coaching and other academic assistance for all UNLV undergraduate students. For information regarding tutoring subjects, tutoring times, and other ASC programs and services, visit <http://www.unlv.edu/asc> or call 702-895- 3177. The ASC building is located across from the Student Services Complex (SSC). Academic success coaching is located on the second floor of the SSC (ASC Coaching Spot). Drop-in tutoring is located on the second floor of the Lied Library and College of Engineering TEB second floor.

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**UNLV Writing Center** — One-on- one or small group assistance with writing is available free of charge to UNLV students at the Writing Center, located in CDC-3-301. Although walk-in consultations are sometimes available, students with appointments will receive priority assistance. Appointments may be made in person or by calling 702-895-3908. The student’s Rebel ID Card, a copy of the assignment (if possible), and two copies of any writing to be reviewed are requested for the consultation. More information can be found at: <http://writingcenter.unlv.edu/>.

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**Rebelmail** — By policy, faculty and staff should e-mail students’ Rebelmail accounts only. Rebelmail is UNLV’s official e-mail system for students. It is one of the primary ways students receive official university communication such as information about deadlines, major campus

events, and announcements. All UNLV students receive a Rebelmail account after they have been admitted to the university. Students' e-mail prefixes are listed on class rosters. The suffix is always @unlv.nevada.edu. **Emailing within WebCampus is acceptable.**

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**Library Resources** — Students may consult with a librarian on research needs. For this class, the subject librarian is [https://www.library.unlv.edu/contact/librarians\\_by\\_subject](https://www.library.unlv.edu/contact/librarians_by_subject). UNLV Libraries provides resources to support students' access to information. Discovery, access, and use of information are vital skills for academic work and for successful post-college life. Access library resources and ask questions at <https://www.library.unlv.edu/>.

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**Final Examinations** — The University requires that final exams given at the end of a course occur at the time and on the day specified in the final exam schedule. See the schedule at: <http://www.unlv.edu/registrar/calendars>.