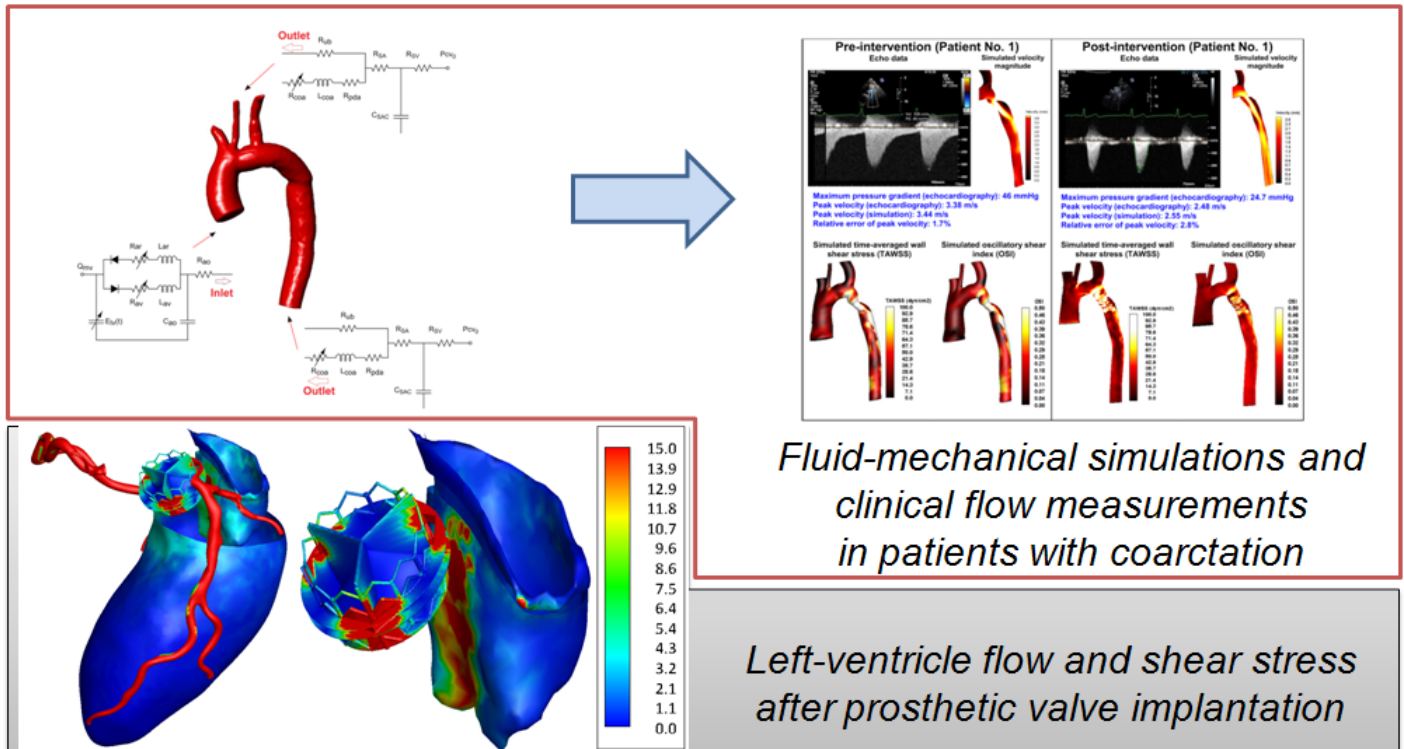


MECH ENG 762 Computational Modeling of Circulatory System



http://mech.mcmaster.ca/faculty/about_keshavarz.motamed.html

Instructor: Dr. Zahra K. Motamed
Office: JHE A416
Email: motamedz@mcmaster.ca
Office hours: TBD

Teaching Assistants: TBD

Lectures: Monday, 10 AM to 1 PM
Tutorials: TBD
Laboratories: none

Course website: via *Avenue to Learn* (avenue.mcmaster.ca)

Course Description & Objectives:

The circulatory system consists of the heart and a network of vessels that transport the blood. The heart consists of two pulsatile pumps in series and circulates blood through the vasculature. The vasculature consists of arteries, arterioles, capillaries, venules and veins. The circulatory system also includes local circulation subsystems such as cerebral, pulmonary and renal circulations. Mechanics of the circulatory system may be studied from two biomechanical perspectives: solid mechanics of the blood vessels and fluid mechanics of the blood flow. The main objectives of the course are to learn basics of modeling of circulatory mechanics and getting familiar with the current challenges involved in the modeling process. Computational modeling of circulatory system presents formidable mathematical and computational challenges: modeling must incorporate motions of blood and vessel walls, complex biomechanics of the heart, a large network of the blood vessels with complicated geometries, persistent pulse-driven changes in flow and pressure, complicated exchanges happening in local circulatory subsystems and in some cases behavior of blood cells. After a brief review of circulatory physiology and fluid mechanics, the course will progress from modeling blood flow in small-scale steady/pulsatile to model large-scale or complex pulsatile flow. This course will cover various methods for modeling mechanics of the circulatory system and its subsystems. We will discuss the application of these concepts in the development of circulatory medical devices (e.g., stents, grafts, heart valves and ventricular assist devices).

Significance:

The main purpose of modeling circulatory mechanics is to study circulatory diseases. *In vivo* measurements are difficult, and even impossible in some cases. Non-invasive measurements are useful but do not always allow studying realistic conditions. Computational modeling of the circulatory system can fill this gap by playing major roles in uncovering causes of pathologies, in enabling prediction of effectiveness of interventions, in allowing systematic testing of possible clinical solutions, and in enabling personalization of interventions. Additionally, development and innovation of extra-corporal systems strongly rely on knowledge of the circulatory mechanics. Therefore, modeling is crucial for design and development of medical devices, and for evaluating of the hemodynamic effects of medical devices after implantation in the patient body.

Course Topics:

Major topics to be covered include:

- Introduction to anatomy and physiology of cardiovascular system
- Introduction to anatomy and physiology of local circulations such as cerebral, pulmonary and renal circulations
- Blood rheology
- Flow, pressure and wave reflection in the circulatory system
- Governing equations for solid deformation
- Governing equations for fluid motion
- Analytical solutions
- Medical imaging technologies
- Medical imaging data used for modeling
- Solid mechanics models
- Fluid mechanics models
- Fluid-solid mechanics models
- Numerical modeling of wave propagation
- Lumped parameter mathematical models

Audience:

This course has been designed for graduate students in science and engineering interested in learning about circulatory mechanic and its biomedical applications. The course will be of particular interest of students in the following departments and schools:

Mechanical Engineering, Chemical Engineering, Computing and Software, Electrical and Computer Engineering, Engineering Physics, School of Biomedical Engineering and School of Computational Science & Engineering. Students from the Faculty of Health Sciences are also welcome to register for the course.

Email Policy:

All emails directed to the instructor should include a subject prefix of “ME [course number]-[subject]”.

Course Materials:**Lecture Notes:**

The lectures notes will be made available on *Avenue* at least two days before each lecture. The lectures notes do not always repeat materials from supplementary references.

Textbook:

There is no specific textbook for this course. The instructor will provide reading material including course notes, articles, videos and schematics. Following are some useful references for the course:

- Chandran KB, Rittgers SE, Yoganathan AP (2012) *Biofluid Mechanics: The Human Circulation*, Second Edition, CRC Press, Taylor & Francis Group.
- Nichols W, O'Rourke M, Vlachopoulos C (2011) *McDonald's Blood Flow in Arteries*, Sixth Edition, CRC Press, Taylor & Francis Group.
- Waite L (2007) *Applied Biofluid Mechanics*, McGraw Hill.
- Waite L (2006) *Biofluid Mechanics in Circulatory Systems*, McGraw-Hill .
- Kleinstreuer C (2006) *Biofluid Dynamics: Principles and Applications*, CRC Press, Taylor & Francis Group.
- Zamir M (2000) *The Physics of pulsatile flow*, Springer-Verlag NY.

Evaluation:

The final grade will be calculated by combining homework, presentations, term project and the final exam as follows. The percentage marks will be converted to a final letter grade using the standard conversion scale shown in the McMaster Graduate Calendar.

Homework:	20% (There will be four assignments)
Presentations:	30% (Two presentations: project proposal and final project presentation)
Term project:	30% (Written report to describe the project)
Final Exam:	20% (Closed book exam)

Term Project: All students will be required to work on a research project individually. The final deliverable will be a written research report. Each student may select a topic (not related to their thesis research) and will prepare a 5 page (single spaced, including any figures, not including references). The research report should be written as a scientific journal article and should include the following

sections: abstract, introduction, methodology, results, discussion and conclusion. Some potential topics (but not limited to) are offered below:

- Any of the topics outlined in the course syllabus such as blood rheology, modeling of solid mechanics, fluid mechanics, wave propagation, heart function and cardiac mechanics in the circulatory system, etc.
- Design, test, and clinical use of blood-bearing artificial organs: ventricular assist devices, heart valves, stents and grafts, etc.
- Modeling for circulatory surgical planning
- The effects of mechanical forces on circulatory cell types: red blood cells, platelets, white blood cells, endothelial cells, etc.
- Biomechanics of cerebral circulation, renal circulation or pulmonary circulation
- Biomechanics of cardiac malformations: aneurysm, stenosis, etc.
- Biomechanics of congenital heart diseases
- Biomechanics of ventricular contraction
- Biomechanics of coronary arteries

Presentation: Each student will give two presentations: first about the project proposal (Mid October) and second at the end of the semester following submission of the final project report.

Guideline: Guidelines for project report and presentations will be given to the students at the beginning of the course.

Exams: There will be a closed book final exam. For that, the instructor will provide the students with a sheet containing all related formulas and unit conversions.

Homework: Homework will be assigned via *Avenue* and due the following week. There will be 4 homework assignments, and therefore there will not be homework every week. Homework solutions will be posted on the class website one week after the homework due date. Any assignment turned in after the due date will be deducted 10 percentage points for every day it is late until the solutions are posted.

Attendance: Class attendance is *highly recommended*. Sample problems will be outlined in class that cannot be found in the reading material. Some of these problems appear in the exam.

Class Website: All registered students will have access to the class website via *Avenue* (avenue.mcmaster.ca). Class announcements, course information, instructor and teaching assistant information, course documents, and assignments are contained on this website. This website will be continuously updated with related information throughout the semester.

Learning Outcomes:

Upon successful completion of the course, it is expected that the students will be able to:

- Understand the physiology and anatomy of the circulatory system
- Understand the blood rheology
- Understand the governing physics of solid and fluid mechanics as applied to the circulatory system
- Know specific circulatory diseases and how they are related to mechanics
- Understand fluid and solid mechanics models currently used for circulatory research problems

- Understand the effect of mechanical forces on various circulatory cells
- Understand biomechanical issues in select circulatory medical devices
- Be familiar with the state of the art computational modeling methods
- Have the understanding and the capability to develop simple models of circulatory function under varying preload, afterload, and contractility
- Have the understanding and the capability to develop simple models of blood flow in devices and circulatory system
- Have the understanding and the capability to develop simple models of stress and strain in blood vessels and heart tissue
- Develop critical thinking regarding the current research challenges in circulatory mechanics
- Have the understanding and the capability to carry out a circulatory-mechanics research project

Policy Reminders: Students are reminded of the following Policies, which could be relevant to activities in this course.

Adverse Discrimination: The Faculty of Engineering is concerned with ensuring an environment that is free of all adverse discrimination. If there is a problem that cannot be resolved by discussion among the persons concerned, individuals are reminded that they should contact the Department Chair, the Sexual Harassment Officer or the Human Rights Consultant, as soon as possible.

Academic Integrity (Ethics and Dishonesty) Academic dishonesty consists of misrepresentation by deception or by other fraudulent means and can result in serious consequences, e.g. the grade of zero on an assignment, loss of credit with a notation on the transcript (notation reads: "Grade of F assigned for academic dishonesty"), and/or suspension or expulsion from the university.

It is your responsibility to understand what constitutes academic dishonesty. For information on the various kinds of academic dishonesty please refer to the Academic Integrity Policy, specifically Appendix 3, located at: http://www.mcmaster.ca/senate/academic/ac_integrity.htm

The following illustrates only three forms of academic dishonesty:

1. Plagiarism, e.g. the submission of work that is not one's own or for which other credit has been obtained.
2. Improper collaboration in group work
3. Copying or using unauthorized aids in tests and examinations.

The instructor and university reserve the right to modify elements of the course during the term. The university may change the dates and deadlines for any or all courses in extreme circumstances. If either type of modification becomes necessary, reasonable notice and communication with the students will be given with explanation and the opportunity to comment on changes. It is the responsibility of the student to check their McMaster email and course websites weekly during the term and to note any changes.