

McMaster University

Faculty of Engineering | Department of Mechanical Engineering

MECHENG

4X04 & 4XA3

Research Projects Booklet

Academic Year 2026–2027

A collection of faculty-proposed research and design projects for undergraduate students.

10+

Projects
Available

Department of Mechanical Engineering | Faculty of Engineering | McMaster University

Students are encouraged to contact faculty members directly to discuss potential project opportunities.

For questions and project inquiries, visit: eng.mcmaster.ca

Project Directory

MECHENG 4X04 & 4XA3 · Academic Year 2026–2027

Connect with Faculty

Students are encouraged to reach out directly to faculty members whose research interests align with their own. If you have an idea for a project, research initiative, or independent study, you are welcome to view the faculty directory and contact the relevant faculty member to discuss potential opportunities within their area of expertise.

View Faculty Directory: eng.mcmaster.ca/faculty-staff/faculty-directory

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How to Use This Booklet

Each project entry includes course delivery tags, faculty contact information, research keywords, and a full project description. Click any project title in the table above to jump directly to that project.

Why Take MECHENG 4X04 / 4XA3?

- Work directly with a professor in your area of interest
- Tackle a real research problem with no predetermined answer
- Strengthen your resume
- Collaborate with graduate students and researchers
- Access state-of-the-art laboratories and equipment
- Develop skills in research, technical writing, and presenting
- Flexible and highly customizable projects
- Gain experience and explore accelerated paths for graduate studies by combining 4X04/4XA3 with 6X04/6XA3

MESSAGE FROM THE ASSOCIATE CHAIR, RESEARCH

A Message from the Associate Chair

Research is about curiosity, discovery, and solving problems that do not yet have answers. Through MECHENG 4X04 and 4XA3, students have the opportunity to experience research firsthand by working directly with a faculty member on a project aligned with their interests and career goals.

Over the course of an academic year (4X04) or a single term (4XA3), students become part of an active research environment within the Department of Mechanical Engineering. They work alongside faculty members, graduate students, and research teams, gaining exposure to state-of-the-art equipment, advanced engineering tools, and cutting-edge research challenges. Whether your interests lie in artificial intelligence, robotics, aerospace, manufacturing, materials, biomechanics, energy systems, or fluid mechanics, these courses provide a unique opportunity to explore a topic in depth while developing valuable research and problem-solving skills.

The courses are highly customizable and emphasize the research process itself. Students learn how to review scientific literature, formulate research questions, design and conduct investigations, analyze results, and communicate their findings through written reports and presentations. Along the way, they gain experience that can strengthen applications for graduate school, support future career opportunities, and build lasting connections with faculty mentors.

For students considering graduate studies, the Department also offers graduate-credit versions of these courses, MECHENG 6X04 and 6XA3. These courses provide an opportunity to undertake advanced research and scholarly dissemination activities while creating a pathway toward accelerated progression into a Master of Applied Science (MAsc) degree or even a Doctorate of Philosophy (PhD).

I encourage you to explore the opportunities presented in this booklet and discover how undergraduate research can become one of the most rewarding experiences of your engineering education.

S. Andrew Gadsden

Associate Chair, Research

Canada Research Chair in Intelligent and Cognitive Engineering

Department of Mechanical Engineering, McMaster University

1

MECHENG 4X04

Bio-Epoxy Unidirectional Flax Fiber Polymer Composite Impact Toughness

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Composites

Natural Fibers

Materials Science

Sustainability

Epoxy fiber reinforced composite materials are used in a variety of applications including automotive, aerospace, and the construction industries. Currently, glass, carbon, and aramid fibers are used as reinforcement. Transitioning to natural fiber reinforcements such as flax fibers is a promising step toward reducing the environmental impact of composites. Flax fibers offer renewability, lower carbon footprints, and biodegradability compared to synthetic counterparts.

However, the waxy surface of flax fibers promotes weak interfacial adhesion between the natural fibers and the polymer matrix, reducing composite mechanical properties and increasing moisture absorption. To mitigate this, flax fibers can be treated with stearic acid – a long-chain saturated fatty acid that is biodegradable and eco-friendly. Stearic acid provides a hydrophobic barrier, improving adhesion with polymers and reducing moisture uptake.

Project Scope

The project entails reviewing the literature and selecting stearic acid treatment concentrations (at least 3) and soak times (at least 3). The goal is to improve the impact toughness and reduce the water absorption of bio-epoxy flax fiber composites. Following flax fiber treatments, composites will be manufactured using the vacuum infusion process.

Testing & Methods

- Test samples cut to 63.5 mm × 12.7 mm × 3 mm (l×w×t) and tested using the Izod impact test per ASTM D256-26
- Water absorption tests conducted over a 30-day period until saturation, with daily weight measurements
- Volume fraction measurements and weight gain analysis from stearic acid treatments
- Scanning Electron Microscopy (SEM) to visualize fiber surface morphology
- Fourier Transform Infrared Spectroscopy (FTIR) to confirm stearic acid presence on fiber surfaces

Expected Outcomes

Results will be compiled into graphs and tables highlighting differences in impact toughness between pure flax, bio-epoxy, and flax/epoxy composites. These results will be used to draw conclusions on the effectiveness of stearic acid treatments for improving impact toughness and moisture absorption.

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MECHENG 4X04

MECHENG 4XA3

Intelligent and Cognitive Engineering (ICE) Laboratory: F26–W27 Research Projects

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Robotics

AI / Machine Learning

Estimation & Control

Aerospace

The Intelligent and Cognitive Engineering (ICE) Laboratory offers multiple cutting-edge research projects for the Fall 2026–Winter 2027 academic year. Students with strong research interests may also propose their own projects aligned with the lab’s expertise areas.

1 Motion Capture for Robotic Manipulation and Space Applications

In collaboration with MDA Space

Explores advanced motion capture technology to improve the performance, accuracy, and intelligence of robotic systems. Students will work with a robotic arm and state-of-the-art motion capture equipment to collect and analyze movement data, develop tracking and control algorithms, and investigate applications in autonomous manipulation and human-robot interaction. Applications include space robotics, autonomous servicing, advanced manufacturing, and intelligent robotic systems.

2 Spacecraft Tracking and Estimation Using CubeSat Data

Focuses on the development and application of estimation algorithms for tracking an experimental CubeSat. Students will investigate techniques such as Kalman filtering and other modern state estimation methods to determine the spacecraft’s position, velocity, and overall state using sensor data. Research involves simulation, sensor fusion, uncertainty analysis, and performance evaluation, providing experience with technologies widely used in aerospace navigation, autonomous systems, and intelligent sensing applications.

3 Agentic and Explainable Artificial Intelligence for Engineering Applications

In collaboration with Adastra

Artificial intelligence is increasingly being used to support engineering decision-making, but ensuring AI systems are transparent, trustworthy, and capable of autonomous reasoning remains a significant challenge. This project will explore the development of agentic and explainable AI systems that can perform complex tasks while providing understandable explanations for their decisions. Students will investigate modern AI frameworks, autonomous agents, large language models, and explainability techniques with real-world engineering applications.

4 AI-Enabled Reverse Engineering of Electronic Systems

In collaboration with the Canadian Centre for Electron Microscopy (CCEM) at McMaster

Investigates the use of artificial intelligence and computer vision to support the reverse engineering of electronic devices, printed circuit boards (PCBs), and integrated circuits. Students will analyze high-resolution imaging data and develop automated methods for identifying, classifying, and interpreting electronic components and structures. The project combines machine learning, image processing, and advanced microscopy to address challenges in hardware analysis, quality assurance, and intelligent inspection.

5 Student-Initiated Research Projects

Students with strong research interests are encouraged to propose their own project ideas aligned with ICE Laboratory activities. Potential areas include artificial intelligence, machine learning, robotics, autonomous systems, estimation and control, aerospace engineering, digital twins, intelligent sensing, and human-machine interaction. Students will work closely with faculty and graduate researchers to develop a project matching their interests and gaining hands-on experience in advanced engineering research and innovation.

3

MECHENG 4X04

Vibration Control of Cutting Tools Using Non-Newtonian Media

Phil Koshy • koshy@mcmaster.ca • www.philkoshy.com

Machining Vibration Control Fluid Dynamics Manufacturing

Vibration of cutting tools often limits productivity in machining. Uncontrolled vibration can adversely affect workpiece surface finish and may damage the cutting/machine tool. The dynamic performance of a cutting tool may be enhanced by increasing its stiffness and/or damping.

Increasing tool stiffness by changing material (e.g., from steel to carbide) entails higher cost and weight. Increasing stiffness by changing geometry may not be possible in internal machining operations such as boring, where the tool diameter is determined by the diameter of the hole being machined. This leaves an increase in damping as the only viable option.

The Non-Newtonian Approach

Unlike a Newtonian fluid – for which viscosity is constant and an inherent property of the fluid – the viscosity of non-Newtonian media (such as a mixture of cornstarch and water) can change by several orders of magnitude. Depending on how they are deformed, the medium can behave like a fluid or a solid. This project will explore the feasibility of enhancing damping in cutting tools using non-Newtonian media.

Project Objective

The objective of this project is to exploit this interesting fluid-solid transition to enhance passive damping and improve the dynamic performance of a boring bar.



Left: boring bar machining setup. Right: non-Newtonian fluid behaviour demonstration.

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MECHENG 4X04

Injury Biomechanics Projects

Cheryl Quenneville • quennev@mcmaster.ca

Biomechanics

Sports Safety

Impact Testing

Protective Equipment

Several potential areas of research exist in injury biomechanics. Students with strong problem-solving skills, self-motivation, and organizational ability will thrive in this course. Faculty are also open to discussing alternate scenarios with qualified and enthusiastic students.

1 Foam Degradation in Hockey Neck Protectors

Neck protectors that provide impact attenuation use foams, but little is known about their degradation over time. Investigations could include quantifying the effect of washing, sweat, hair products, and repeated bending from movement, or developing a method to evaluate 'comfort' of a hockey neck guard in a quantifiable way — for example, using a bending resistance machine.

2 Instrumentation System for 3D-Printed Helmets

3D printing has been adopted by the helmet industry to target protective properties in different directions while enabling light-weight design and recoverability post-impact. Testing flat isolated samples often leads to different performance than the same material integrated into a full-scale helmet. This project involves designing a small instrumentation system that can be embedded into a 3D-printed helmet to directly measure normal and shear strain components during a drop tower test using a headform.

3 Evaluation of Baseball Elbow Protectors

Elbow protectors are worn by many baseball athletes, but little is publicly known about their design, capabilities, or what a test standard should look like. Building on previous work quantifying the fracture tolerance of the elbow from a direct blow and instrumenting a surrogate in that location, this project will evaluate how much energy is attenuated by assorted commercial elbow guards and what design features provide the best protection.

4 Ski Binding Release Analysis Across Anatomical Variations

Ski bindings are tested for their ability to release when a given force is applied, with the boot and loading direction aligned with the ski. Given the range of anatomies (particularly sex differences), the hypothesis is that 'bow-legged' or 'knock-kneed' individuals may not have their boot release at the appropriate load. This project involves designing a jig to adjust the axis of loading in precise increments and testing the release force of ski bindings.

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MECHENG 4X04

MECHENG 4XA3

Rowing / Sailing / Sprint Canoe (and Sprint Kayak) Boat Aero-Hydrodynamics

Dr. S. Tullis • stullis@mcmaster.ca

Fluid Dynamics

Sport Engineering

Hydrodynamics

Aerodynamics

A range of possible projects exist in boat aero-hydrodynamics, with details to be worked out with the student. Racing experience in one of the listed boat types is a prerequisite for this project.

Potential Project Areas

Rowing Athletes as Power Sources

Experimental testing of athletes as power sources. Modelling of boat drag with pitching and wave-making resistances.

Sailing Aero-Hydrodynamic Modelling

Modelling of aero-hydrodynamics. Topics could include twin-skin sails, hull aerodynamics, foils, and foil ride-height control.

Canoe & Kayak To Be Determined

Project specifics are to be determined. The student would need to be an active member of a competitive club.

Note

Racing experience in one of the listed boat types is a prerequisite. Contact Dr. Tullis to discuss your background and project ideas before applying.

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MECHENG 4X04

MECHENG 4XA3

Flows in Foamy Liquids

Dr. S. Tullis • stullis@mcmaster.ca

Fluid Mechanics

Steelmaking

Heat Transfer

Experimental Research

Foams come in two main types: those with very high amounts of gas (like dish soap or shampoo) and much wetter frothy foams (like a frothy beer). Wetter foams are common in industry – in steelmaking, liquid slag floats on liquid steel and is purposely foamed up to provide benefits including reduced heat loss and lower noise and emissions. Heat is carried effectively by the foamy slag, useful in transferring heat to cold scrap steel being melted in the furnace.

Project Background

The behaviour of foamy slag in electric arc steelmaking furnaces is the main driver of this project, which is part of a larger initiative on computational modelling in steelmaking. Modelling foamy slag flow and heat transfer is an important component of the overall project, and experimental data is needed to validate the computational models against simpler foamy liquid flow experiments.

Experimental Setup

This 4X project involves performing experiments using a benchtop cold flow rig. Gas (air) is injected into the bottom of a pool of liquid (silicone oils or glycerine), causing the liquid to foam up. The custom-built rig offers variable flow configurations and far greater control of gas injection than commercial alternatives, including novel cases where gas is not injected uniformly.

Focus Areas

- Novel cases where gas is not injected uniformly, driving circulation patterns via rising bubbles in the foam
- Dye injection for tracking convection in the foamy liquid
- Testing on a range of liquids and gas flow configurations (flowrates, distributor setups)
- Collaboration with a graduate student working on computational modelling of foamy slag

Note

Experience with steelmaking is useful but not required. Enthusiasm for hands-on experimental investigation of something completely new is, however, definitely required.