Undergraduate Summer Research Award
Proposed Projects
APPLICATION DEADLINE: February 14, 2025 – 11:59 pm

Please review a sample of the posted summer research projects below. Reach out to the faculty members for more information. Projects are not limited to this list; You are welcome to discuss other projects with faculty members, these are a place to start.

Dr. Barbara da Silva (Barbara.dasilva@queensu.ca)
Field: Fluid Dynamics and Heat Transfer

Project Title: **Smooth sailing with rotor sails: Numerical simulations**

Rotor sails are a promising wind-assisted propulsion system to help reduce the reliance of the maritime sector on fossil fuels. Co-supervised with Prof. John Kurelek, the student will investigate the flow dynamics around a rotor sail, using computational fluid dynamics (CFD) simulations.

Dr. Barbara da Silva (Barbara.dasilva@queensu.ca)
Field: Fluid Dynamics and Heat Transfer

Project Title: **Computational fluid dynamics simulations of separated flows**

Separated flows are widespread in the aerospace and energy sectors, but they can be notably difficult to simulate, with trade-offs between simulation accuracy and computational cost. Hybrid turbulence modeling approaches may offer, however, a compromise between these features. The student will be trained in the open-source CFD toolset OpenFOAM and perform CFD simulations to examine the performance of different models.

Dr. Barbara da Silva (Barbara.dasilva@queensu.ca)
Field: Fluid Dynamics and Heat Transfer

Project Title: **The strange wake of a wall-mounted block: Unveiling the flow around a PCB Component**

Improved cooling strategies are required in data centres to decrease their electricity consumption. A PCB component, represented by a wall-mounted block, has a unique wake with vortical components unlike the ones found for taller obstacles. The student will investigate these features and how they affect the mixing and heat transfer in the wake under different conditions.

SMITH ENGINEERING Queen's University — Mechanical and Materials Engineering

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Barbara da Silva (Barbara.dasilva@queensu.ca)
Dr Field: Fluid Dynamics and Heat Transfer

Project Title: **Development of a pulsatile water tunnel for fluids research**

The student will participate in the upgrade and commissioning of an experimental facility to investigate the effects of pulsating flow on the wake of wall-mounted obstacles. The student will acquire hands-on experience on experimental fluid mechanics, instrumentation and flow measurement techniques.

Dr. Brian Surgenor (brian.surgenor@queensu.ca)
Field: Mechatronics and Manufacturing

Project Title: **Slip-Correction Techniques for Improving Dead Reckoning in Wheeled Robots**

Dead reckoning is a navigation method used to estimate a mobile robot's current position based on a previous position, relying on inertial data or odometry. While prone to accumulating errors over time, this method is often indispensable in unstructured environments or when external signals are unavailable, such as in off-road applications. The challenge is to find a way to correct for wheel slippage in a mobile robot, which is the source of the error. A recently completed Master's thesis set out to evaluate various compensation methods, using a Vicon motion tracking system to generate ground truth. This USRA project would continue this work, which has yet to be verified against rough and uneven terrain.

Dr. Heidi-Lynn Ploeg (heidi.ploeg@queensu.ca)
Field: Biomechanics

Project Title: **Orthopaedic biomechanics with mechanical testing of bones**

Dr. Il Yong Kim (kimiy@queensu.ca)
Field: Systems Design

Project Title: **DfAM (design for additive manufacturing) for automotive & aerospace lightweight design**

Based on design optimization and topology optimization, the project will conduct multi-physics modeling, analysis, and design optimization of parts & assemblies considering metal & polymer additive manufacturing, with applications in automotive and aerospace design.

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Dr. Il Yong Kim (kimiy@queensu.ca)
Field: Systems Design

Project Title: **Carbon fibre reinforced plastic (CFRP)-based lightweight design for automotive & aerospace structures**

Achieve lightweight and cost-effective designs for automotive & aerospace parts, considering modeling and optimization of the number of layers, stacking sequences, fibre orientation, geometry, and joining methods.

Dr. Il Yong Kim (kimiy@queensu.ca)
Field: Systems Design

Project Title: **Machine Learning-based optimization for energy and aerospace industries**

Develop hybrid design optimization methods based on machine learning and standard optimization, for rapid and effective simulation and design of hydro-turbine systems and aerospace systems.

Dr. Jackson Crane (jackson.crane@queensu.ca)
Field: Thermodynamics

Project Title: **Detonation testing apparatus development**

Detonation diagnostics development: A new class of engines is poised to disrupt the aviation and rocket propulsion sectors, with theoretical efficiencies 40% higher than the state-of-the-art. These engines, called detonation engines, use shock waves to efficiently compress fuel. Despite intense international research efforts, development engines are not achieving the performance theoretically predicted, in part due to detonation instabilities. This project is to develop new ways to understand and modulate detonation instabilities. Students will work with high-speed diagnostics, optical techniques such as Schlieren visualization, and gas handling. This project is primarily experimental in nature.

Dr. Laurent Béland (Laurent.beland@queensu.ca)
Field: Computational Materials Science

Project Title: **Machine learning to identify good collector molecules to improve lithium and rare earth elements extraction from ore**

In collaboration with CanmetMINING and researchers in the mining and chemical engineering department, the student will use molecular modelling techniques augmented by machine learning to discover molecules that selectively bind to lithium and rare-earth elements containing minerals, and make them hydrophobic, allowing to separate them from the ore using a technique know as frothing flotation.

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Dr. Laurent Béland (Laurent.beland@queensu.ca)
Field: Computational Materials Science

Project Title: **Predicting how radiation damage evolves over long timescales**

the student will focus on materials to be used in small modular reactors (Ni- and Fe-based alloys). In collaboration with researchers at the Canadian Nuclear Laboratories, CanmetMATERIALS, MIT, Universite de Montreal, in France, in Italy and in Croatia, the student will develop and use a state-of-the-art atomistic simulation software package to study how damage produced by neutron ages over timescales currently inaccessible by conventional atom-scale simulations. To do so, they will employ strategies from the world of machine learning, materials science and physical chemistry.

Dr. Laurent Béland (Laurent.beland@queensu.ca)
Field: Computational Materials Science

Project Title: **Computational study of molten salts and corium for nuclear reactor applications**

Molten salts are considered as a primary and secondary coolant for next generation nuclear reactors. Corium is a liquid mixture of fuel and cladding that can be formed in case of a conventional nuclear reactor meltdown. There are many unknowns which pertain to the physical properties (viscosity, heat capacity, melting point, heat conductivity, etc.) of these fluids. The student will employ machine-learning accelerated molecular simulations to study these fluids and provide collaborators specializing in fluid mechanics at the Canadian Nuclear Laboratories with the necessary physical properties to perform higher fidelity fluid simulations of molten salts and corium.

Dr. Laurent Béland (Laurent.beland@queensu.ca)
Field: Computational Materials Science

Project Title: **Computational study of hydrogen embrittlement of copper**

Project in partnership with the nuclear waste management organization of Canada. All-atom computer simulations to understand how hydrogen is stored in copper, and how it affects its mechanical properties.

Dr. Laurent Béland (Laurent.beland@queensu.ca)
Field: Computational Materials Science

Project Title: **Find how we can convert CO2 to plastic using electrocatalysis**

We would run a mix of all-atom computer simulations and machine learning methods.

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Dr. Lidan You (you.lidan@queensu.ca)
Field: Biomechanics

Project Title: **Bone-Cancer cross talk under mechanical loading**

Mechanical loading plays a critical role in maintaining bone health, as bone cells are highly sensitive to mechanical stimuli. Evidence has demonstrated active cross-talk between bone and cancer under mechanical loading. However, the cellular and molecular mechanisms driving this interaction remain poorly understood. This study aims to investigate the role of microproteins in mediating the cross-talk between bone and cancer under mechanical loading, providing new insights into the underlying biological processes.

Dr. Mark Daymond (mark.daymond@queensu.ca)
Field: Nuclear Materials

Project Title: **Design, Build and Test experimental equipment**

The student will work at the Reactor Materials Testing Laboratory at Queen's University designing, building and testing a piece of experimental equipment. The RMTL is a nuclear regulated accelerator facility, which allows irradiation of samples with a proton or alpha particle beam, emulating the conditions found inside a nuclear reactor or in outer space. The goal of the experiments is to understand the aging and degradation of materials, and hence to assist with prediction of material response inside a reactor – however to be able to run those experiments we have to build our own experimental apparatus that can be placed at the end of the existing accelerator beamline, with the added complication that everything is running in a vacuum. The undergraduate student will work with graduate students, postdocs and technical staff to develop the design, and then implement and test their design. Depending on the interests of the student, the project allocated could be mostly mechanical design or could also include electrical, electronics or computing aspects. Familiarity with Arduino or similar to allow PC control would be an advantage.

Dr. Roshni Rainbow (Roshni.rainbow@queensu.ca **)**
Field: Biomechanics

Project Title: **Engineering musculoskeletal tissues during inflammation**

Dr. Vahid Fallah (Vahid.fallah@queensu.ca)
Field: Materials and Manufacturing

Project Title: **Design and build of a laser-scan imaging system (based on low-coherence interferometry) to be integrated into an SLM metal 3D printer**

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Dr. Vahid Fallah (Vahid.fallah@queensu.ca)
Field: Materials and Manufacturing

Project Title: **Developing and implementing AI-based algorithms for in-situ monitoring/control of metal 3D printing process**

Dr. Xian Wang (xian.wang@queensu.ca)
Field: Mechatronics and Robotics

Project Title: **Microrobot for Mechanical Measurement of Cancer Cell**

The project focuses on the development of microrobots for the mechanical measurement of cancer cells, combining microrobotics with mechanical analysis. These microrobots, guided with precision using external magnetic fields, are designed to probe the mechanical properties of individual cancer cells and tissues at the microscale. By analyzing how cells respond to mechanical forces, we aim to uncover distinct mechanical properties of cancer cells and tissues. The student will gain expertise in microrobot design, control systems, biomechanics, and instrumentation.

Dr. Xian Wang (xian.wang@queensu.ca)
Field: Mechatronics and Robotics

Project Title: **Robotic Arm for Precision Measurement and Automation**

Our project focuses on designing an Arduino-based robotic arm system for precision measurement applications. This robotic arm, equipped with high-resolution sensors and actuators, is controlled using an Arduino microcontroller, enabling precise and repeatable motion. The system is tailored for applications such as force measurement, dimensional analysis, and automated sample handling in research and industrial environments. By integrating real-time control algorithms and modular hardware, the robotic arm offers a cost-effective and customizable solution for diverse measurement tasks. The student will gain hands-on experience in robotic design, Arduino programming, sensor integration, and control system development.

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Dr. Yanwen Zhang (Yanwen.zhang@queensu.ca)
Field: Nuclear Materials

Project Title: **Understanding Ion energy Deposition to Multi-Elemental Targets Using SRIM Simulations**

Stopping and Range of Ions in Matter (SRIM) programs calculate the interaction of ions with matter. This project explores how ion energy is deposited in materials and compares different simulation methods for predicting radiation damage. Students will use the SRIM software to simulate ion irradiation in various materials, such as SiC, CeO_2, ZrO_2, ZrN, and $SrTiO_3$. Specifically, they will compare two different simulation approaches: full-cascade and quick Transport of Ions in Matter (TRIM) modes, to see how each predicts the damage produced by ion impacts. The project will help students understand how the composition of materials and the mass and energy of ions affect the results. Students will also examine the role of specific material properties, like displacement energies, in these simulations. This hands-on project will give students practical experience in radiation damage simulations and offer insights into the strengths and limitations of SRIM simulations for ion-material interactions.

Dr. Yanwen Zhang (Yanwen.zhang@queensu.ca)
Field: Nuclear Materials

Project Title: **Evaluating the Overestimation of Electronic Stopping Power in SRIM for Heavy Ions in Light Targets**

Stopping and Range of Ions in Matter (SRIM) and Transport of Ions in Matter (TRIM) are software tools used to simulate how energetic ions interact with materials. In this project, students will learn about the overestimation of electronic stopping power in SRIM for MeV heavy ions (such as gold, Au, or bismuth, Bi) in light targets or compounds containing light elements, such as O and C in SiC, TiC, ZrC, and $SrTiO_3$. Students will compare the results from SRIM simulations with real experimental data from published studies. They will focus on ion range and damage profiles, and look at the differences between predicted and experimentally observed results. The project will also involve exploring ways to correct for SRIM's overestimation and testing whether these corrections improve the accuracy of the simulations. By the end of the project, students will gain a deeper understanding of how ions interact with solids, the challenges involved in simulating radiation damage, and the importance of improving current models to make more accurate predictions.

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Dr. Yanwen Zhang (Yanwen.zhang@queensu.ca)
Field: Nuclear Materials

Project Title: **Comparative Study of Light and Heavy MeV Ions in Modifying Solid Materials Using SRIM**

Stopping and Range of Ions in Matter (SRIM) and Transport of Ions in Matter (TRIM) are software tools used to simulate how energetic ions interact with materials. This project focuses on understanding how protons, helium ions, and heavy ions at MeV energies modify solid materials, such as metal alloys and ceramics. Students will use the SRIM/TRIM code to simulate the interaction of these ions with target materials, comparing the resulting damage profiles, ion ranges, and energy deposition mechanisms. Key aspects of the project include:

1. Comparing energy loss mechanisms (nuclear vs. electronic stopping) for light and heavy ions, and analyzing how these differences affect damage production;
2. Understanding how the mass and energy of the ions influence the depth and distribution of damage in a solid;
3. Discussing the implications of these findings for applications such as ion implantation in semiconductors, radiation effects in materials, or space radiation shielding.

This project will provide students with hands-on experience in ion-solid interaction simulations, an understanding of radiation damage mechanisms, and insights into the practical differences between light and heavy ion irradiation. It is well-suited for undergraduate students with an interest in materials science, nuclear engineering, or radiation effects in nuclear materials.