SMITH ENGINEERING Queen's University — **Mechanical and Materials Engineering**

Undergraduate Summer Research Award
Proposed Projects

APPLICATION DEADLINE: February 13

This is a sample of the summer research projects. 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. Laurent Béland (laurent.beland@queensu.ca)
Field: Computational Materials Science

Every summer, Dr. Béland takes on undergraduate students who want to try computational materials research. Students will learn how to use supercomputers to explore materials at the atomic level and work on projects like building AI models, running simulations, or creating visualization tools. You don't need any prior experience; just curiosity, problem-solving skills, and an interest in how computing and materials science come together.

Sample projects include:
Project Title 1: **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.

Project Title 2: **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.

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Project Title 3: **Find how we can convert CO2 to plastic using electrocatalysis**
We would run a mix of all-atom computer simulations and machine learning methods.

Project Title 4: **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.

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

Project Title: **Liquid-Spray detonation**

Undergraduate research researchers are paired with a graduate student in the areas of liquid-spray detonation. There may be opportunities to work with graduate students doing experimental research in supersonic combustion with application to high-efficiency engines.

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Dr. Barbara da Silva (barbara.dasilva@queensu.ca)
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. This project involves hands-on experience on experimental fluid mechanics, instrumentation and modern flow measurement techniques.

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Dr. Claire Davies (claire.davies@queensu.ca)
Field: Biomechanics and Assistive Devices

Project Title 1: **Supporting Clients with Disabilities in the Building and Designing Assistive Technology (BDAT) lab.**

Clients with disabilities approach the Building and Designing Assistive Technology (BDAT) Lab to design assistive technologies to increase their independence. Depending on the clients, the research assistant may be required to 3D print, use Arduino programming, or other prototyping techniques to design a device with the client in a co-creation approach. The summer student will be expected to work with Kids Inclusive in the redesign of battery-operated cars to increase independence of children with mobility issues.

Past research has shown that independent mobility is linked to cognitive, social, motor, language and other developmental benefits in young children. Being carried, as well as being pushed in a stroller or a wheelchair is fundamentally different from having active control over one's own exploration. When children are given access to active control that is where the developmental gains are seen. The ride-on adapted cars provide the kids a fun experience that promotes their independent mobility while experiencing therapeutic benefits, building muscle control and muscle memory and learning about their environment. Depending on the needs of the child, this will include re-wiring a car to be switch activated either through a touch sensor, proximity sensor, or head mounted sensor. Modifications to these cars may include: switch access - the use of a switch to make the car go rather than the need to press a pedal, sensors - detection of obstacles within the environment, speed monitoring, roll bars - foam and pool noodles to support the child with postural control difficulties.

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Project Title 2: **Eye Tracking**

Eye-tracking selections are made by fixating on a specific area of the screen for a predetermined length of time, known as the dwell time. It is difficult to distinguish between an exploratory fixation, when a person is searching on the screen for a specific icon, versus a fixation with the intent to select a target. Inadvertent selections occur if a user pauses on an icon for longer than the dwell time that is set for the system. Dynamic dwell time (DDT) algorithms that vary dwell time within a task use metrics such as probability of selection and past performance to manipulate the dwell time of individual targets and increase the usability of eye-tracking systems. Two modes of manipulation can occur, adaptive or adaptable. Adaptive modes are those that rely on a computer algorithm to change the dwell time, while adaptable modes rely on the user to self-select dwell times (that can vary depending on fatigue levels, knowledge of the system etc). The student will work to develop an adaptive algorithm that learns from the user how much time is needed for dwell time selection. They will work with typically developing users (n=10) to identify the key metrics involved in dwell time manipulation. Next, they will evaluate adaptive and adaptable dwell times with both individuals from the typical population (n=20).

Tasks will include:
1) the evaluation of eye-tracking algorithms that are reliable and efficient when detecting pupil features (size, movement etc)
2) algorithm development that uses pupil and eye movement features to click on icons
3) development of an algorithm that chooses between adaptive (user selected dwell time on an icon) vs adaptable (dwell time selected through machine learning algorithms)

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

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

The Mechanics of Nuclear Materials group at Queen's looks after RMTL, a state of the art accelerator facility. With it, we can introduce radiation damage into materials, emulating what happens inside a nuclear reactor. It's a large and active team, with lots of opportunities to work with industry and travel. We are looking for both graduate students and undergraduates for a summer, with openings for those

- interested in materials degradation, mechanical testing and/or electron microscopy
- wanting to design and build components for the accelerator facility. That would include mechanical design and control (e.g. Arduino) aspects

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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.

Project Title 1: **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.

Project Title 2: **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.

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Dr. Yongjun Lai (lai@queensu.ca)
Field: MEMS / Mechatronics

Project Title 1: **Wearable Sensors for Intraocular Pressure Monitoring**
The project will design, prototype and testing of contact lens sensors for intraocular pressure measurement. It will involve with nanowire patterning, and transferring, polymeric material processing, and sensor design and testing.

Project Title 2: **Embedded system for machine condition monitoring**. The project will implement vibrational energy harvesters with wireless sensing nodes to realize self-sustainable capacity for long life and maintenance-free machine condition monitoring. The project will involve coding for embedded system, including data acquisition, edge computing, communication etc.

Project Title 3: **AI-assisted biosensing.** The project will develop AI-assisted analysis for collected signals from MEMS biosensors, to enhance the sensors sensitivity and selectivity. The summer student will involve with some experimental data collection, while his/her main focus will be on modeling and signal processing.

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Dr. Qingguo Li (ql3@queensu.ca)
Field: Biomechanics

Project Title 1: **Exoskeleton Development**

The Bio-Mechatronics and Robotics Laboratory (BMRL) is seeking a summer research student to contribute to an innovative project focused on developing energy-autonomous lower-limb exoskeleton solutions. This research aims to enhance real-world mobility, particularly for individuals facing mobility challenges, such as the elderly and those carrying heavy loads (e.g., soldiers and first responders).

Our program investigates inter-limb cross-joint exoskeletons that integrate energy harvesting with active assistance to significantly reduce the metabolic cost of walking while minimizing reliance on external power sources. Building on our recent pioneering work, we have demonstrated that controlled braking at the knee during the late swing phase of walking can reduce metabolic costs by 2.5% and generate free electricity (0.25W), challenging the traditional notion that exoskeletons must inject power to provide benefits.

As a research assistant, you will play a key role in biomechanical system modeling and design, prototyping and testing, instrumentation development, data collection, and analysis of biomechanical measurements related to exoskeleton performance. This position offers the opportunity to contribute to high-impact research aimed at improving the quality of life for individuals with mobility limitations.

Project Title 2: **Wearable system-based intervention for reducing work-related musculoskeletal disorders (WMSDs) in clinical settings**

WMSDs are highly prevalent among healthcare workers due to sustained awkward postures, prolonged task durations, and the use of heavy lead aprons. To mitigate the risk of WMSDs, Dr. Li and his graduate students at the Bio-mechatronics and Robotics Laboratory (**www.bmrlab.ca**) are developing wearable sensors and soft exoskeleton solutions to provide posture feedback and mechanical support for medical staff during procedures in the operating room.

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Undergraduate researchers will collaborate with graduate students to develop new sensor feedback methods, design soft exoskeletons, and evaluate their performance in simulated operating room procedures. They will have the opportunity to work with clinicians at the Sunnybrook Health Sciences Centre (SHSC) to achieve user-centered design and promote musculoskeletal health for healthcare professionals. The ultimate goal is to develop the next generation of a smart protection system to improve occupational health in clinical environments.

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

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

Queen's Bone and Joint Biomechanics (Q-BJB) Lab focuses on developing biomechanical solutions for the prevention, care and treatment of diseased or injured bones and joints. We are always looking for students with an interest and willingness to learn about bone and orthopaedic implant biomechanics, mechanical testing or computational modelling. Students must be good at working and communicating in teams.

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

Project Title 1: **Ion-Solid Interaction Simulations for Radiation Damage Prediction**

How do energetic ions impact materials at the atomic level? This summer project invites a curious undergraduate intern to explore this question through simulation-based research, focusing on the fascinating world of ion–solid interactions. When ions penetrate a material, they lose energy by colliding with atoms and exciting electrons, processes that drive defect formation, material modification, and radiation damage. Predicting how and where these changes happen is essential for designing radiation-hardened materials for electronics, space missions, and nuclear applications. The project emphasizes learning by doing: the intern will be mentored through step-by-step SRIM (Stopping and Range of Ions in Matter) simulations, guided data interpretation, and collaborative discussions to uncover how ion–solid interactions shape material response.

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Project Title 2: **Radiation Effects in Wide-Bandgap Semiconductors for Extreme Environments**

Wide-bandgap (WBG) semiconductors, such as GaN, AlN, BN, AlGaN, and Ga_2O_3, are at the forefront of innovation in power electronics, aerospace systems, and next-generation energy technologies due to their excellent electrical performance, thermal stability, and radiation resistance. These properties make them ideal for extreme environments, such as space missions, nuclear reactors, and fusion systems. However, their long-term functionality depends on how they respond to radiation-induced damage at the atomic scale.

This research project investigates the fundamental mechanisms of radiation–solid interactions in WBG semiconductors through a focused literature review and computer-based simulations using the SRIM (Stopping and Range of Ions in Matter) software. The project explores how energetic particles, such as ions and neutrons, create point defects, disrupt charge transport, and affect the structural and electronic stability of these materials. Emphasis will be placed on understanding trends in defect formation, annealing behavior, carrier trapping, and breakdown mechanisms across different WBG systems. Using SRIM, students will simulate ion irradiation in selected semiconductors, gaining insight into how ion mass and energy influence damage profiles. These simulations will complement the literature review and provide a hands-on perspective on how modeling tools can predict radiation effects in advanced materials.