Undergraduate Research Opportunities in Mechanical Engineering

University of Alberta
2012
Research Options

• Dean's Research Award (DRA) Program
• NSERC Undergraduate Student Research Award (USRA) Program
• Transition to Graduate (Masters) Program
• NSERC Postgraduate and Canada Graduate Scholarship Program
• Alberta Ingenuity Graduate Student Scholarships
DRA Program

- Open to academically superior undergraduates (GPA > 3.2 in previous term)
- Participation provides research experience and training in research methodology
- 1 term duration, 1 half day per week
- $500 is provided after the successful delivery of a one page abstract and 10 minute presentation of the terms work.
- A low risk introduction to the research process.
- Apply by mid January 31st, but can start sooner.
USRA Program

• NSERC USRAs are for full time work (16 weeks) in the natural sciences or engineering research fields. Could be co-op or summer placement.
• NSERC provides $4500, supervisor/department provides the rest for a minimum expected wage of $6750
• Offers opportunity to do original research
• Possibility of peer reviewed journal/conference publications resulting from the work.
• Eligibility requirements are on www.nserc.gc.ca
USRA Program

• Department needs applications by January 23rd.
• Adjudication of applications will occur and students will be ranked based on GPA, seniority, research potential/past experience, commitment to a graduate program and a few other factors
• GPA and year of study are the most important
• 8 allocated USRAs are available to mechanical engineering this year.
Ranking and awards

• All students will be ranked
• A category ranks will be automatically chosen for the USRA should they choose to take the position
• If anyone on the A list chooses not to take a USRA, the first spot on the B list will be offered a position.
• This continues until all allocations are filled
• Students should be contacted starting sometime in late March on whether they were successful
Why USRA are important

• If you are interested in graduate studies at all, it is an excellent position to hold
• Demonstrates seriousness and greatly aids in your chances to successfully obtain a Masters’ level scholarship from NSERC
• Potential for academic publications out of your work while still in undergraduate – great on CV’s and looks good to graduate schools
• A relatively risk free way to determine if graduate school is a good fit for you.
More information

• Information on DRA, USRA and other research opportunities are found on our website:

Transition to Graduate program

• For those students interested in graduate programs but without external scholarships, direct funding can be provided by the department and potential supervisors
• Funding can be in the form of TA’s, RA’s and direct funding
• Dependent on budgets of individual professors and department
• Ask individual professors about programs and projects – there may be money available
A bit about Professors and areas of Interest

• Professors will often advertise positions for DRA, USRA or graduate opportunities
• You can make your own opportunities by approaching professors individually and asking about potential work
• This information is just a sample of what current research areas are open within the Mechanical Engineering Department
Designing Microparticles for drug delivery applications using spray drying.

Studying drying of individual microdroplets with laser technology.

Developing new measurement methods and instruments for particle and aerosol analysis.
Energy Systems Design Lab

**Computational Design and Optimization of Energy Systems**
- Fuel cell systems for Arctic conditions
- Fuel cell stack analysis
- Flywheel design for energy storage

**Computational Analysis of Energy systems**
- OpenSource PEM fuel cell analysis framework
- Two-phase flow analysis in fuel cells
- Multi-component mass transport analysis in fuel cells

**Experimental Testing of Energy Systems**
- Ultra-low platinum loading fuel cell fabrication
- Fuel cell testing under varied operating conditions
- Analysis of gas transport in fuel cell electrodes

For more information visit:
http://www.mece.ualberta.ca/groups/energysystemsdesign/

Lab Director:
Dr. Marc Secanell
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• DRA projects available
  • Testing of ultra-thin polymer electrolyte fuel cell electrodes for automotive applications
  • Experimental determination of the permeability and effective diffusivity of fuel cell electrodes
Use of a Conventional Epoxy Resin as a Shape Memory Material (SMM)

Supervisor: Dr. Cagri Ayranci

Shape Memory Materials (SMM), such as Shape Memory Polymers (SMP), can store a temporary shape and restore their original shape upon application of an external stimulus, such as heat.

Video:
Recovery of the permanent shape from the temporary shape (tubular structure)

Possible Applications:
- Structural members of Micro Aerial Vehicles (MAVs)
- Multifunctional space structures

Shape Memory Polymers (SMPs)
- Easy to process
- Light weight
- High strain rates
Use of a Conventional Epoxy Resin as a Shape Memory Material (SMM)

Supervisor: Dr. Cagri Ayranci

Project Description:
Investigation of thermo-mechanical and shape memory properties of a conventional epoxy resin system.

Tasks:
• Casting of epoxy resin using different hardener-to-resin weight ratios
• Differential Scanning Calorimetry (DSC) and Dynamic Mechanical Analyzer (DMA) analysis to determine the Glass Transition Temperatures (Tg) of the different specimens
• Shape recovery ratio characterization of different hardener-to-resin weight ratio specimens

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- Micro and nanofabrication
- Polymer micromachining
- Dry adhesives – “gecko glue”
- Micro-assembly
- Micro-robotics
Particle Engineering for Respiratory Drug Delivery

Aerosol Delivery

Engineered Particles

50x smaller than a human hair

Spray Dryer
Mechanics of aerosols for drug delivery to the lung

- worldwide collaborations in fight against lung disease
- experiments with fluids and aerosols in respiratory tract and inhalers
- development of nanofabricated particles for inhaled pharmaceutical aerosol delivery to the lung
- use of computational fluid dynamics and numerical methods to enhance our understanding and design of respiratory delivery
VfDL Flow Control Research:

1 Automobile-Trailer Aerodynamics
2 Robo-Step Separated Flow Control
3 Digital Microfabrication / DNA Microarrays
Vortex Fluid Dynamics Lab

- Structure and Control of Turbulent Vortex Structures – drops, bubbles, jets, turbulence, ..
- Strengths in visualization, Applications to DNA microarrays, digital material printing, bluff body aerodynamics, smoke/flare stacks, orifice plate flow meters, pipelines
Brian Fleck: research
http://www.mece.ualberta.ca/~ckoch/TECLab.html

• **Current Projects**
• Improving the atomization performance of nozzles in two phase flow for oilsands cokers
• Mixing of impinging and counterflow jets in crossflows to simulate hazardous atmospheric releases
• Study of droplet entrainment and drag reduction in thin sheared liquid layers
• Practical evaluation of residential wind turbines in Alberta
C. R. (Bob) Koch

Professor, Univ. of Alberta since 2001
DaimlerChrysler (Stuttgart) 1991 - 2001
Ph.D. (Stanford 1991)

Interested in Control
of Thermofluid Systems

Control of:
1. Internal combustion engines (HCCI)
2. Electromagnetic valves
3. droplets, thin films, jets, airfoils and particle separation

e-mail: bob.koch@ualberta.ca
http://www.mece.ualberta.ca/~ckoch/
• **Water Vapour Cycle on Mars** (Phoenix Mars Lander Mission), funded by the Canadian Space Agency.
• Assist with validation experiment, Mars simulation and data interpretation from Mars surface operations.
Biomedical flows:
  - Cough analysis and airborne transmission prevention:
    • Image processing of high-speed droplet break-up during artificial cough

Flu-Pandemic Control

Transmissor:
• antiviral
• antibacterial
• symptom treatment

Environment:
• surgical mask
• face shield
• quarantine
• bioaerosol suppressant

Recipient:
• vaccine
• immune system boost
Subir Bhattacharjee

Research Areas:
- Microfluidic devices
- Microscale heat transfer
- Water treatment technologies
- Environmental Engineering

Opportunities:
- Experience in interdisciplinary research
- Exposure to international conferences
- Research in the growth area of nanotechnology

Facilities:
Atomic force microscope, fluorescence microscope, Linux cluster, access to Micro/Nanofab.

If you want to explore fundamental sciences, check us out at: http://www.mece.ualberta.ca/~subir
Surface Engineering & Instrumentation

Alidad Amirfazli
www.mece.ualberta.ca/staff/alidad

Laser micro-patterning

Microgravity Experiments

Biomechanics of Knee

Canadian Space Agency

Super-hydrophobic Surface

Industry Collaboration International experience
Quantitative Damage Evaluation/Acoustic Radar System

Professor Xiaodong Wang
(Advanced Structures and Materials Laboratory)

- **Received sensor signals**
- **Image of the damage**
- **Regeneration of wave propagation**

- Now developing new integrated sensor systems and imaging techniques
- Applications: Material identification, Aerospace structures, MEMS, Pipeline
Current studies are focused on fracture toughness of ductile polymers and fibre composites.

- Ultrasonics examination
- Contact mechanics
- Quantification of mechanical properties
Dr. J. Carey

Research interests

Biomechanics/biomedical engineering

- Cardiovascular
- Artificial joint design
- Golf biomechanics
- Orthodontic appliance design/modeling
- Tissue mechanics

Composite materials

- Golf shaft design
- Catheter design
- Composite materials theory
- Braiding
- Extrusion

Room 5-8T
Jason.carey@ualberta.ca
P. SCHIAVONE – RESEARCH TOPICS

Dr. Schiavone is engaged in fundamental scientific research (no fancy pictures, no promises of big $$ or commercial success – just interesting and thought-provoking scientific research) on elasticity and the analysis of mathematical models to predict the mechanical behaviour of advanced materials.

Specifically:

• Mathematical Theory of Linear Elasticity
• Linear Piezoelectrics
• Plate Theory
• Cosserat Solids (microstructure effects)
• Composite Mechanics
• Boundary Integral Equation Methods in Mechanics
• Complex Variable Methods in Elasticity
The ACME Group is recognized internationally for innovative research related to advanced materials such as fibre-reinforced composites. The overall objectives of the research program are:

• obtaining a thorough understanding of the mechanical properties of advanced materials under multiaxial loads and severe environmental conditions;
• evaluating the strengthening effect of reinforcement under multiaxial stress states;
• formulating appropriate constitutive models which can be implemented in a general purpose finite element program to aid in design and analysis of industrial components;
• developing a theory to predict fatigue life/long term behaviour of advanced materials under multiaxial loading;
• implementing research results into prototype structures such as high-pressure piping and vessels, and energy-storage flywheel rotors.

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Dr. Zihui Xia
Professor

Dr. Pierre Mertiny
Assistant Professor
Advanced Computational Group Activities
for more info contact Dr. Walied Moussa walied.moussa@ualberta.ca

Sub-Structuring Finite Element Models

Non-linearity
Sub-structure
Sub-Model

Health Monitoring of Aging Aircraft

- Photonic sensors Suite
- Distributed signal preprocessing
- Integrated avionics

MEMS

Intelligent Materials

Shape Memory

Nano-scale medical robots
Reliable Integrated Oil Sands Systems
Prof. Mike Lipsett

- Controlling the reliability of a system
  - with process constraints or interdependencies
- Developing model-based understanding of complex systems
  - such as oil sands bitumen production
- Developing new, more sustainable oil sands production methods

**Novel Bitumen Production Systems**
- small environmental footprint

**Shovels:**
- remote monitoring & control
- discrete-event control / local exception handling
- direct condition monitoring
- ore grade sensing (spectral pattern classification)
- diagnostics & life prediction

**Trucks:**
- fleet allocation / blending
- autonomous navigation
- diagnostics

**Crush & Slurry:**
- controlled comminuting
- diagnostics & life prediction

**Pumping & Separation:**
- pump and pipeline process & equipment diagnostics
- controlled conditioning
- model predictive control of separation

**Maintenance Management:**
- inspection & repair methods
- decision support for prioritization & resource allocation
GLOBAL WARMING

CLIMATE CHANGE

KYOTO PROTOCOL

GREENHOUSE GAS MITIGATION

Renewable Energy Systems

Bioenergy Systems (straw, trees, forest residues etc.)

Biopower Generation

Biofuels
Ethanol, Bio-oil, Biodiesel

Techno-Economics
Greenhouse Gas Credits
Simulation and Modeling
Large Scale Biomass Transport Pipeline

Decision Support Systems

BC's Mountain Pine Beetle

For further information contact:
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$$ - Students with Scholarships will get Supplemental Stipends - $$
Key Results – Alberta Energy Flow Sankey Diagram Without Exports
Key Results – Alberta Energy Flow Sankey Diagram With Exports

Sustainable Energy Research Laboratory (SERL)
Amit.Kumar@ualberta.ca
Key Results – Alberta Emission Flow Sankey Diagram
Machinery Condition Monitoring & Reliability Enhancement

Dr. Ming Zuo at ming.zuo@ualberta.ca

- Condition Monitoring
- Signal Processing
- Fault Diagnosis
- Reliability Enhancement

Fourier Transform
- Frequency Spectrum
- Number of frequency components
- Value of each component
- Amplitude of each component

Advanced Techniques
- Wavelet Analysis: For transient component identification and de-noising
- Neural Networks: For intelligent diagnosis and maintenance optimization
- Blind Source Separation: For isolation of multiple sound or vibration sources
- Support Vector Machine: For pattern recognition and prediction of equipment remaining life

The System
- Sensor
- Signal Conditioner
- A/D Converter
- Laptop Computer
- Driving Software
Stanislav Karapetrovic
Industrial Engineering / Quality Systems

• Engineering of quality systems

• Integration of management systems

• ISO 9000 / ISO 10000
Dr. Kajsa Duke

• Research focus in orthopaedic biomechanics

• Potential DRA, co-op, MSc and Phd projects

Kajsa Duke
Assistant Professor
Mechanical Engineering

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Scoliosis & Spine Surgery

• Pressure measurements at the patient and cushion interface while lying on the operating table
• Future work, data collection, improve monitoring or cushion design

Kristen Sabourin, co-op student

kkduke@ualberta.ca
Fracture fixation

• Custom plate design and screw placement optimisation
• Future work, design refinement

James Huber, DRA student

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Jin-Oh Hahn
System Dynamics & Controls; Biomedicine, Automotive, Energy Systems

• Biomedicine
  – Physiological Modeling, Monitoring & Disease Diagnostics
  – Computer-Controlled Drug Delivery Systems

• Automotive Systems
  – Road Condition Monitoring, Driver Assistance Systems
  – Powertrain Control

• Energy Sectors
  – Wind Turbine Condition Monitoring & Control
Sushanta K. Mitra

Research Theme: Microfluidics and Nanofluidics for Biological and Energy Applications

Research Lab: Micro and Nano-Scale Transport Lab (NINT 06-065)

Biological Applications:
- BioMEMS sensor for detection of Stress Protein
- Handheld Biosensor for cardiac markers
- Lab-on-a-Chip for Vitamin detection
- Dielectrophoresis for cell separation

Energy Applications:
- Pore-scale modeling of oil/water/gas in porous reservoir
- Microfluidics platform for CO₂ sequestration and EOR
- Bioconversion of coal
- Micro Fuel Cells – PEMFC and SOFC

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What is graduate study?

• Undergraduate courses: basic tools and knowledge to do engineering work
• Graduate Courses: additional knowledge to solve technical R & D problems
• Thesis: solve a technical research problem that no one has solved before
  – MSc: problem where method is standard
  – PhD: complex, difficult problem (multifaceted); method may be new
Why enter graduate study?

• Why did you go to University?
  – Intellectual growth
  – Job satisfaction (leads to more interesting, life-long challenging career)

• Why did you excel in University?
  – Who will recognize this?
Job satisfaction/ Flexibility

• With a graduate degree:
  – Tend to have higher technical challenge
  – Can do technical work longer
  – Ability to choose projects
  – Higher technical background allows you to tackle interesting multi-disciplinary projects - Exciting
Graduate School – No life like it

• Grad school is not like undergrad – far more fun and satisfying.
• Professors are training you to become colleagues and equals
• You get to tackle advanced problems that interest you and develop new solutions to novel problems
• Grad school teaches you to become self-reliant/self-motivated and provides extra highly technical training to work in advanced industries
• Your co-workers/lab mates/supervisors are high achieving and motivated – a highly enriching work environment
NSERC Application Process

• Application is now online, but UofA’s FGSR needs a hard copy this year
• You need to gather two references and an official transcript in addition to your application
• References should be people familiar with you and your work
• Choose your references wisely!