SFU GRADUATE STUDIES

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MEMORANDUM

ATTENTION Senate

DATE May 16, 2024

FROM Mary O'Brien,
Chair of Senate Graduate Studies Committee (SGSC)

RE: New Courses

For information:

Acting under delegated authority at its meeting of May 7, 2024, SGSC approved the following new courses, effective **Spring 2025**:

Faculty of Applied Science

School of Engineering Science

1) New Course: ENSC 812 Synthetic Aperture Radar; Backscatter and Interferometry Applications
2) New Course: ENSC 845 Programming for Heterogeneous Computing Systems (effective Fall 2025)
3) New Course: ENSC 871 Optical and Laser Engineering Applications
4) New Course: ENSC 875 Biomedical Instrumentation
5) New Course: ENSC 884 Robotics: Motion and Control I

School of Mechatronics Systems Engineering

1) New Course: MSE 753 Hybrid Thermal Electric Microgrids I
2) New Course: MSE 754 Hybrid Thermal Electric Microgrids II (effective Summer 2025)

Senators wishing to consult a more detailed report of curriculum revisions may do so on the Senate Docushare repository at https://docushare.sfu.ca/dsweb/View/Collection-12682

OFFICE OF THE DEAN
Faculty of Applied Sciences
Simon Fraser University

MEMORANDUM

Attention Dr. Mary O'Brien
Dean, Graduate Studies

Date: April 2, 2024

From Dr. Parvaneh Saeed, psaeedi@sfu.ca
Faculty of Applied Science, Graduate Studies Committee

Re: FAS multiple course changes

The faculty of Applied Sciences Graduate Studies Committee would like to request the following course changes to be included in the next Senate Graduate Studies Committee meeting.

1. Conversion of the following special topic courses to permanent new courses:

- ENSC 812 - Synthetic Aperture Radar; Backscatter and Interferometry Applications (formerly ENSC 895 - Special Topics III)
- ENSC 845 - Programming for Heterogeneous Computing Systems (formerly ENSC 894 - Special Topics II)
- ENSC 871 - Optical and laser engineering applications (formerly ENSC 894 - Special Topics II)
- ENSC 875 - Biomedical Instrumentation (formerly ENSC 895 - Special Topics III)
- ENSC 884 - Introduction to Robotics (formerly ENSC 894 - Special Topics II).

2. Course change

- ~~ENSC 805 - Advanced Digital Communication~~
- ~~ENSC 813 - Deep Learning Systems in Engineering~~

We would request the changes to be projected in the University calendar for Spring 2025.

Regards,
Parvaneh Saeedi

SFU FACULTY OF APPLIED SCIENCES | SCHOOL OF ENGINEERING SCIENCE

MEMORANDUM

BURNABY

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8888 University Drive
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Canada

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ATTENTION	**Dr. Parvaneh Saeedi** **Associate Dean, Research & Graduate Studies**
FROM	Dr. Mirza Faisal Beg Chair, ENSC Graduate Program Committee
RE	ENSC New Courses and Course Changes
DATE	March 18, 2024

Please accept the following new course proposals and course change requests, which have been updated per feedback received recently from the Senate Graduate Studies Committee (pre-SGSC):

New course proposals:

ENSC 812, ENSC 845, ENSC 871, ENSC 875, ENSC 884

- The School of Engineering Science Graduate Studies Committee (ENSC GPC) would like to request converting these frequently offered Special Topics courses to regular graduate courses by submitting the new course proposals. The rationale for the change is to provide better scheduling when offering these combined courses, reduce confusion to students during enrollment and generating transcripts. These are anticipated to appear in the University calendar for Spring 2025.

~~**Course changes:**~~

~~**ENSC 805** – The ENSC GPC would like to request changing the ENSC 805 course pre-requisite. The rationale for the change is to make the course accessible to a larger group of students.~~

~~**ENSC 813** – The rationale for this prerequisite change is to make~~ this ~~course more accessible to graduate students across SFU.~~

SFU GRADUATE STUDIES

NEW GRADUATE COURSE PROPOSAL

Course Subject (eg. PSYC) ENSC	**Number** (eg. 810) 812	**Units** (eg. 4) 3

Course title (max. 100 characters) Synthetic Aperture Radar; Backscatter and Interferometry Applications

Short title (for enrollment/transcript - max 30 characters) SAR Backscatter and In. App.

Course description for SFU Calendar *(course descriptions should be brief and should never begin with phrases such as "This course will..." or "The purpose of this course is..." If the grading basis is satisfactory/unsatisfactory include this in the description. Max. 50 words)

A review of the principles of Synthetic Aperture Radar (SAR) and Interferometric SAR (InSAR) Remote Sensing and its Applications. An overview of the basic theory of is presented, linking SAR with related coherent imaging techniques (e.g. optical holography, MRI, and sonar/ultrasound) and providing an understanding of the capabilities and limitations of complex SAR data and their key land and marine applications. The focus is on interferometric SAR (InSAR) methods and applications, including generation of topographic maps as well as advanced time series analysis for measuring ground surface motion associated with seismic displacement, compaction related subsidence, volcanic inflation, and landslides.

Rationale for introduction of this course

Spaceborne and airborne SAR are complex engineering systems with growing importance (particular SAR satellite platforms are steeply incresisng in numbers with many new systems being planned or already been launched and operated by both national and private entities) and a multitude of powerful applications for earth observation monitoring applications (urban and industrial infrastructure integrity, natural hazards, agriculture, met-cocean observations, and maritime security) . It is important for engineering students to understand the basics of SAR, including how it relates to that behind other coherent imaging and tomographic techniques used by various engineering systems (e.g. optical holography, MRI, e.g. sonar/ultrasound) as well as its key applications, including relevant sensor design and signal formation; basic and advanced SAR and InSAR data processing methods, Knowledge gaine din teh course will allow students to assess the feasibility of existing and new applications and test new data processing methods of SAR and InSAR, and understand the challenges around their design for concrete cases they may encounter in their later careers. The course teaches SAR/InSAR "techniques and applications as a component to be used in various engineering systems.

Term of initial offering (eg. Fall 2019) Spring 2025	**Course delivery** (eg 3 hrs/week for 13 weeks) LEC 3 hrs/week for 13 weeks; LAB 5 hrs for 13 weeks
Frequency of offerings/year annual or bi-annual	**Estimated enrollment per offering** 15

Equivalent courses (courses that replicates the content of this course to such an extent that students should not receive credit for both courses)

Students with credit for ENSC 461 under the title "Synthetic Aperture Radar; Backscatter and Interferometry Applications" may not take this course for further credit.

Prerequisite and/or Corequisite

Permission of instructor. Recommended prerequisites: ENSC 251, 316

Criminal record check required? ☐ Yes (if yes is selected, add this as prerequisite) | **Additional course fees?** ☐ Yes ☑ No

Campus where course will be taught ☑ Burnaby ☐ Surrey ☐ Vancouver ☐ Great Northern Way ☐ Off campus

Course Components* ☑ Lecture ☐ Seminar ☑ Lab ☐ Research ☐ Practicum ☐ Online ☐ Other: _____

Grading Basis ☑ Letter grades ☐ Satisfactory or Unsatisfactory ☐ In Progress/Complete

Repeat for credit? ☐ Yes ☑ No	**Total repeats allowed?** _____	**Capstone course?** ☐ Yes ☑ No
Required course? ☐ Yes ☑ No	**Final exam required?** ☐ Yes ☑ No	**Repeat within a term?** ☐ Yes ☑ No

Combined with an undergrad course? ☑ Yes ☐ No If yes, identify which undergraduate course and what the additional course requirements are for graduate students:

ENSC 461 (to be created simultaneously), graduate course has higher grading weight on the individual course project (more challenging topics for grads + including delivery a journal style paper on the project results)

* See important definitions on the curriculum website.

RESOURCES

If additional resources are required to offer this course, provide information on the source(s) of those additional resources.

Faculty member(s) who will normally teach this course
Bernhard Rabus, Rodney Vaughn
Additional faculty members, space, and/or specialized equipment required in order to offer this course
Computer lab access (ssh to SARlab server) for labs and term project

CONTACT PERSON

Academic Unit / Program	**Name (typically, Graduate Program Chair)**	**Email**
Engineering Science	Mirza Faisal Beg	enscgpcc@sfu.ca

ACADEMIC UNIT APPROVAL

☑ A course outline / syllabus is included

Non-departmentalized faculties need not sign

Department Graduate Program Committee Mirza Faisal Beg	**Signature**	Mirza Faisal Beg Digitally signed by Mirza Faisal Beg DN: cn=Mirza Faisal Beg, o=Simon Fraser University, ou=School of Engineering Science, email=mfbeg@sfu.ca, c=US Date: 2024.02.22 16:13:08 -08'00'	**Date**	02/22/2024
Department Chair Cheng Li	**Signature**	Digitally signed by Cheng Li Date: 2024.02.23 17:30:56 -08'00'	**Date**	02/23/2024

FACULTY APPROVAL

The course form and outline must be sent by FGSC to the chairs of each FGSC (fgsc-list@sfu.ca) to check for an overlap in content

overlap check done? ☑ YES

This approval indicates that all the necessary course content and overlap concerns have been resolved. The Faculty/Academic Unit commits to providing the necessary resources.

Faculty Graduate Studies Committee (FGSC)			
Parvaneh Saeedi	**Signature**	Parvaneh Saeedi Digitally signed by Parvaneh Saeedi Date: 2024.04.02 11:43:45 -07'00'	**Date**

A library review will be conducted. If additional funds are necessary, Graduate Studies will contact the academic unit prior to SGSC.

SENATE GRADUATE STUDIES COMMITTEE APPROVAL

Senate Graduate Studies Committee (SGSC)		
Mary O'Brien	**Signature**	**Date** May 16, 2024

ADMINISTRATIVE SECTION (for Graduate Studies office only)

Course Attribute: _____
Course Attribute Value: _____
Instruction Mode: _____
Attendance Type: _____

If different from regular units:
Academic Progress Units: _____
Financial Aid Progress Units: _____

ENSC 812 – Synthetic Aperture Radar; Backscatter and Interferometry Applications

Course proposal

MOTIVATION

Synthetic Aperture Radar (SAR) and Interferometric SAR (InSAR) observation from airborne and spaceborne platforms has powerful geophysical applications (e.g. characterization of ocean and land features, ground displacement of volcano, earthquake, landslide, and glacier hazards). Monitoring applications of man-made phenomena (urban and industrial infrastructure, maritime security, agriculture, etc.) are equally important. Accuracy and acceptance of these applications is rising fast with numbers of satellites equipped with synthetic aperture radar (SAR) sensors rapidly increasing both through national space programs and the recent advent of private small-satellite constellations. Processing methods important for applications of SAR and InSAR, to enhance the original image data and extract information from them, are highly transferable to that of many other engineering systems exploiting coherent synthetic aperture imaging; such as laser holography, seismic tomography and subsea sonar, as well as various coherent medical imaging techniques such as ultrasound or MRI. It is important for engineering students to gain an understanding of key applications of SAR technology. This course reviews basics of SAR and then focuses on SAR backscatter and InSAR earth observation applications. An overview of state of the art InSAR data processing is presented with transfer beyond the radar case.

OBJECTIVES

After completing this course, the students should:

- Understand key concepts, as well as potential, and constraints of SAR interferometry and its applications
- Understand the terminology and be able to follow the literature in the field, including the relation of InSAR techniques to those in other engineering areas where coherent imaging is employed.
- Be able to evaluate feasibility of application design problems involving InSAR, implement an application in the relevant software (currently, the course examples use python based environments and SAR processing software provided by CSA and ESA)

PROPOSED CALENDAR ENTRY

This course reviews the principles of Synthetic Aperture Radar (SAR) and Interferometric SAR (InSAR) Remote Sensing and its Applications. An overview of the basic theory is presented, linking SAR with related coherent imaging techniques (e.g. optical holography)

and providing a solid understanding of the capabilities and limitations of complex SAR data and their key land and marine applications. The course focus is on interferometric SAR (InSAR) methods and applications, including generation of topographic maps as well as advanced time series analysis for measuring ground surface motion associated with seismic displacement, compaction related subsidence, volcanic inflation, and landslides.

PREREQUISITES

Recommended prerequisites: ENSC 251, 316.

TEXTBOOKS

[CW] Ian G. Cumming, Frank H. Wong, *Digital Processing of Synthetic Aperture Radar Data*, Artech House (Boston), 2004. ISBN: 9781580530583. Book website: http://us.artechhouse.com/Digital-Processing-of-Synthetic-Aperture-Radar-Data-P1549.aspx

[HR] Hanssen, Ramon. (2001). Radar Interferometry Data Interpretation and Error Analysis. 10.1007/0-306-47633-9.

[KB] Kampes, Bert. (2006). Radar Interferometry - Persistent Scatterer Technique. 10.1007/978-1-4020-4723-7.

WEEKLY COURSE DELIVERY SYLLABUS

Week 1 – Lecture: Radar and SAR Fundamentals in relation to other coherent imaging
Lab: Math and Python Introduction, Complex calc., Differential Geom. Rev.
Week 2 – Lecture: SAR Land Applications
Lab: Understanding SAR Images; sensor characteristics, image formation
Week 3 – Lecture: SAR Ocean Applications
Lab: Understanding SAR Images; information content + statistical properties
Week 4 – Lecture: InSAR Fundamentals in relation to other coherent imaging
Lab: Interferograms: information + statistical properties, phase unwrapping
Week 5 – Lecture: Basic InSAR Techniques, phase components, simple separations
Lab: Coherence and Filtering, spatial resolution, phase noise optimal trade-off
Week 6 – Lecture: PolSAR Fundamentals
Lab: PolSAR math, classification methods
Week 7 – Lecture: Geodesy background
Lab: SAR imaging for turbulent trajectories; platform motion compensation
Week 8 – Lecture: Basic InSAR Applications (Topography)
Lab: work on Course project
Week 9 – Lecture: Basic InSAR Applications (Differential and 3D Velocity)
Lab: work on Course project
Week 10 – Lecture: Advanced InSAR Techniques (Surface Movement Series)
Lab: InSAR Spatio-temporal phase component separation methods
Week 11 – Lecture: Advanced InSAR Applications (Infrastructure/Unstable Ground)

Lab: work on Course project
Week 12 – Lecture: Advanced InSARTechniques (Pol-InSAR and Tomography)
Lab: Pol-InSAR and Tomography algorithms

COURSE PROJECT

Course projects are performed individually by each student. The students choose their project topics within the first four weeks of the semester, which leaves them nine weeks to work on it. In the past, owing to diverse student backgrounds, project topics ranged from investigating aspects of SAR or InSAR processing methods (e.g. novel designs of phase unwrapping, or adaptive filtering algorithms) to focusing on evaluating a particular application design or designing and carrying out a concrete quantitative case study with real SAR and InSAR data. Sentinel-1 SAR data has been a free data source for student projects in the past. Towards the end of the course, each student prepares a journal-style term paper about their project, methodology, and results. The introduction of this paper must contain a brief summary of InSAR methodology to gauge student understanding of the course content in their own words. Deliverables include the term paper, plus any code or scripts used to derive presented results.

GRADING

30%	Lab Assignments
10%	Class participation
20%	Course project - code/scripts and results (in text and powerpoint format)
40%	Course project - journal-style paper

ENSC 461 – Synthetic Aperture Radar; Backscatter and Interferometry Applications

Course Outline

MOTIVATION

Synthetic Aperture Radar (SAR) and Interferometric SAR (InSAR) observation from airborne and spaceborne platforms has powerful geophysical applications (e.g. characterization of ocean and land features, ground displacement of volcano, earthquake, landslide, and glacier hazards). Monitoring applications of man-made phenomena (urban and industrial infrastructure, maritime security, agriculture, etc.) are equally important. Accuracy and acceptance of these applications is rising fast with numbers of satellites equipped with synthetic aperture radar (SAR) sensors rapidly increasing both through national space programs and the recent advent of private small-satellite constellations. Processing methods important for applications of SAR and InSAR, to enhance the original image data and extract information from them, are highly transferable to that of many other engineering systems exploiting coherent synthetic aperture imaging; such as laser holography, seismic tomography and subsea sonar, as well as various coherent medical imaging techniques such as ultrasound or MRI. It is important for engineering students to gain an understanding of key applications of SAR technology. This course reviews basics of SAR and then focuses on SAR backscatter and InSAR earth observation applications. An overview of state of the art InSAR data processing is presented with transfer beyond the radar case.

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- Understand key concepts, as well as potential, and constraints of SAR interferometry and its applications
- Understand the terminology and be able to follow the literature in the field, including the relation of InSAR techniques to those in other engineering areas where coherent imaging is employed.
- Be able to evaluate feasibility of application design problems involving InSAR, implement an application in the relevant software (currently, the course examples use python based environments and SAR processing software provided by CSA and ESA)

PROPOSED CALENDAR ENTRY

This course reviews the principles of Synthetic Aperture Radar (SAR) and Interferometric SAR (InSAR) Remote Sensing and its Applications. An overview of the basic theory is presented, linking SAR with related coherent imaging techniques (e.g. optical holography)

and providing a solid understanding of the capabilities and limitations of complex SAR data and their key land and marine applications. The course focus is on interferometric SAR (InSAR) methods and applications, including generation of topographic maps as well as advanced time series analysis for measuring ground surface motion associated with seismic displacement, compaction related subsidence, volcanic inflation, and landslides.

PREREQUISITES

MATH 251, ENSC 316; or permission of instructor.

TEXTBOOKS

[CW] Ian G. Cumming, Frank H. Wong, *Digital Processing of Synthetic Aperture Radar Data*, Artech House (Boston), 2004. ISBN: 9781580530583. Book website: http://us.artechhouse.com/Digital-Processing-of-Synthetic-Aperture-Radar-Data-P1549.aspx

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Lab: Interferograms: information + statistical properties, phase unwrapping
Week 5 – Lecture: Basic InSAR Techniques, phase components, simple separations
Lab: Coherence and Filtering, spatial resolution, phase noise optimal trade-off
Week 6 – Lecture: PolSAR Fundamentals
Lab: PolSAR math, classification methods
Week 7 – Lecture: Geodesy background
Lab: SAR imaging for turbulent trajectories; platform motion compensation
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Lab: InSAR Spatio-temporal phase component separation methods
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Lab: work on Course project

Week 12 – Lecture: Advanced InSARTechniques (Pol-InSAR and Tomography)

Lab: Pol-InSAR and Tomography algorithms

COURSE PROJECT

Course projects are performed individually by each student. The students choose their project topics within the first four weeks of the semester, which leaves them nine weeks to work on it. In the past, owing to diverse (undergraduate) student backgrounds, project topics ranged from investigating aspects of SAR or InSAR processing methods (e.g. investigating issues with phase unwrapping or filtering) to focusing on evaluating a particular application in general or by using a case study using real data (at the same time undergraduate topics focus on a single more easily solvable design task, different from more challenging multi-facetted topics of the parallel graduate course). Sentinel-1 SAR data has been a free data source for student projects in the past. Towards the end of the course, each student prepares a short report about their project. The report begins with a brief summary of InSAR methodology in the student's own words to gauge their understanding of the course content (at the undergraduate level) and describes their design methodology, and results. Deliverables include the scientifically formatted report, plus any code or scripts used to derive presented results.

GRADING

40%	Lab Assignments
15%	Midterm quiz
45%	Course project report

SFU GRADUATE STUDIES

NEW GRADUATE COURSE PROPOSAL

Course Subject (eg. PSYC) ENSC	**Number** (eg. 810) 845	**Units** (eg. 4) 3

Course title (max. 100 characters) Programming for Heterogeneous Computing Systems

Short title (for enrollment/transcript - max 30 characters) Prog. for Hetero. Cmpt. Sys.

Course description for SFU Calendar *(course descriptions should be brief and should never begin with phrases such as "This course will..." or "The purpose of this course is..." If the grading basis is satisfactory/unsatisfactory include this in the description. Max. 50 words)

The computing industry has been actively exploring specialized and programmable hardware accelerators, such as GPUs and FPGAs, to bring orders-of-magnitude performance and energy gains for important application domains. It teaches fundamental concepts, designs, and programming of heterogeneous computing systems, including multicore CPUs, GPUs, and FPGAs.

Rationale for introduction of this course

This course started as one of the Special Topics courses. This was offered Summer 2020, Summer 2021, and Fall 2022. It is cross-listed with ENSC 453, which was already converted as a regular course. The School of Engineering Science would now like to turn this graduate course into a regular academic course for better clarity. This course covers emerging technology topics that are both very timely and increasingly relevant.

Term of initial offering (eg. Fall 2019) Fall 2025	**Course delivery** (eg 3 hrs/week for 13 weeks)	Lec: 4hrs/week for 8 weeks Lab: 2hrs/week for 13 weeks Cap: 4hrs/week for 5 weeks
Frequency of offerings/year 1	**Estimated enrollment per offering**	10

Equivalent courses (courses that replicates the content of this course to such an extent that students should not receive credit for both courses)

Students with credit for ENSC 453 or ENSC 894 under the title "Programming for Heterogeneous Computing Systems" may not take this course for further credit.

Prerequisite and/or Corequisite

Recommended Prerequisite(s): ENSC 350 and ENSC 351; or taken equivalent C++ programming and digital system design courses before

Criminal record check required? ☐ Yes (if yes is selected, add this as prerequisite)	**Additional course fees?** ☐ Yes ☑ No

Campus where course will be taught ☑ Burnaby ☐ Surrey ☐ Vancouver ☐ Great Northern Way ☐ Off campus

Course Components* ☑ Lecture ☐ Seminar ☑ Lab ☐ Research ☐ Practicum ☐ Online ✓ Other: Capstone

Grading Basis ☑ Letter grades ☐ Satisfactory or Unsatisfactory ☐ In Progress/Complete

Repeat for credit? ☐ Yes ☑ No	**Total repeats allowed?** _____	**Capstone course?** ☐ Yes ☑ No
Required course? ☐ Yes ☑ No	**Final exam required?** ☐ Yes ☑ No	**Repeat within a term?** ☐ Yes ☐ No

Combined with an undergrad course? ☑ Yes ☐ No If yes, identify which undergraduate course and what the additional course requirements are for graduate students:

ENSC 453. Lab and project components require more advanced programming techniques and more competitive grading.

* See important definitions on the curriculum website.

RESOURCES

If additional resources are required to offer this course, provide information on the source(s) of those additional resources.

Faculty member(s) who will normally teach this course Dr. Zhenman Fang (primary); Dr. Lesley Shannon
Additional faculty members, space, and/or specialized equipment required in order to offer this course Space and equipment are already in place when offering the undergraduate portion ENSC 453

CONTACT PERSON

Academic Unit / Program Engineering Science	**Name (typically, Graduate Program Chair)** Faisal Beg	**Email** enscgpcc@sfu.ca

ACADEMIC UNIT APPROVAL

☑ A course outline / syllabus is included

Non-departmentalized faculties need not sign

Department Graduate Program Committee Mirza Faisal Beg	**Signature** Mirza Faisal Beg Digitally signed by Mirza Faisal Beg DN: c=CA, ou=ENSC, o=Simon Fraser University, cn=Mirza Faisal Beg, email=mfbeg@sfu.ca Date: 2024.02.23 12:25:16 -08'00'	**Date** 02/23/2024
Department Chair Cheng Li	**Signature** Digitally signed by Cheng Li Date: 2024.03.12 23:32:48 -07'00'	**Date** 03/12/2024

FACULTY APPROVAL

The course form and outline must be sent by FGSC to the chairs of each FGSC (fgsc-list@sfu.ca) to check for an overlap in content

overlap check done? ☑ YES

This approval indicates that all the necessary course content and overlap concerns have been resolved. The Faculty/Academic Unit commits to providing the necessary resources.

Faculty Graduate Studies Committee (FGSC) Parvaneh Saeedi	**Signature** Parvaneh Saeedi Digitally signed by Parvaneh Saeedi Date: 2024.04.02 11:44:28 -07'00'	**Date**

A library review will be conducted. If additional funds are necessary, Graduate Studies will contact the academic unit prior to SGSC.

SENATE GRADUATE STUDIES COMMITTEE APPROVAL

Senate Graduate Studies Committee (SGSC) Mary O'Brien	**Signature**	**Date** May 16, 2024

ADMINISTRATIVE SECTION (for Graduate Studies office only)

Course Attribute: _____
Course Attribute Value: _____
Instruction Mode: _____
Attendance Type: _____

If different from regular units:
Academic Progress Units: _____
Financial Aid Progress Units: _____

ENSC 845: Programming for Heterogeneous Computing Systems
Cross-listed with ENSC 453

Course Outline:

With the significant slowdown of general-purpose CPU scaling, the computing industry has been actively exploring specialized and programmable hardware accelerators, such as GPUs and FPGAs, to bring orders-of-magnitude performance and energy gains for important application domains. While GPUs have already made a great success in high-performance scientific computing on supercomputers and the recent deep learning revolution, FPGAs have also attracted increasing attention in datacenters in the past few years. In addition to Microsoft's early deployment of FPGA-based datacenters, major cloud service providers, including Amazon and Alibaba, all announced the public access of their FPGA-enabled cloud. Future computing systems will become even more heterogeneous and will feature a mix of multicore CPUs, GPUs, FPGAs, and other specialized hardware accelerators (e.g., machine learning accelerators like Google TPU and Amazon Inferentia). To get our students prepared and competitive for this hot job market, it is essential for them to understand the fundamental concepts and designs of such heterogeneous computing systems and master skills to program such systems.

In this course, we will teach students fundamental concepts, design principles, and programming techniques for heterogenous computing systems, including multicore CPUs, GPUs, and FPGAs. Specially, this course teaches the following topics:

- Basic concepts of general-purpose computing
- Basic concepts of specialized hardware acceleration
- Multicore CPU programming using OpenMP
- GPU programming using CUDA
- FPGA programming using High-Level Synthesis (HLS) C/C++
- Comparison between multicore CPU, GPU, and FPGA

Recommended Prerequisite: ENSC 350 and ENSC 351; or taken equivalent C++ programming and digital system design courses before

Weekly Lecture Schedule:

Sep 07, 2023	Lecture 1	Introduction **!!Important Grading and Logistics!!**
Sep 12, 2023	Lecture 2	Programming Multicore CPU with OpenMP
Sep 14, 2023	Lecture 3	Performance Optimization for Loop Parallelization (in OpenMP)
Sep 19, 2023	Lecture 4	Race Conditions and Synchronization in OpenMP
Sep 21, 2023	Lecture 5	Understanding the Impact of Memory System on Program Performance
Sep 26, 2023	Lecture 6	Introduction to FPGA and HLS

Sep 28, 2023	Lecture 7	Introduction to FPGA and HLS (cont.)
Oct 03, 2023	Lecture 8	FPGA Acceleration with HLS C/C++: Compute Optimization
Oct 05, 2023	Lecture 9	FPGA Acceleration with HLS C/C++: Memory Optimization
Oct 10, 2023	No Lecture	Happy Thanksgiving!
Oct 12, 2023	Lecture 10	Whole-Program Execution and Best Effort FPGA Programming
Oct 17, 2023	HLS Tutorial | Q/A	Tutorial and Demo
Oct 19, 2023	Lecture 11	FPGA Acceleration Case Study on 2D Convolution
Oct 24, 2023	Student Presentation and Discussion	Project Interim Report
Oct 26, 2023	Student Presentation and Discussion	Project Interim Report
Oct 31, 2023	Student Presentation and Discussion	Project Interim Report and Research Paper Presentation
Nov 02, 2023	Lecture 12	Introduction to GPU and CUDA C
Nov 07, 2023	Lecture 13	CUDA Memory and Data Locality
Nov 09, 2023	Lecture 14	GPU Performance Optimizations
Nov 14, 2023	Student Presentation and Discussion	Research Paper Presentation
Nov 16, 2023	Student Presentation and Discussion	Research Paper Presentation
Nov 21, 2023	Lecture 15	Common Parallel Computation Patterns
Nov 23, 2023	Q/A	Project office hour by TA | TA evaluation
Nov 28, 2023	Student Presentation and Discussion	Project Final Report
Nov 30, 2023	Student Presentation and Discussion	Project Final Report
Dec 05, 2023	Student Presentation and Discussion	Project Final Report

Grading scheme

Tentative grading scheme:

- 45% Lab Assignments (5% for lab 1, and 10% for each of lab 2 to 5)
- 45% Final Project (15% for interim report, 30% for final report)
- 10% Paper Presentation
- 3% Class Participation Bonus
- 2% Course Survey Bonus
- 1% TA Evaluation Bonus (if applicable)
- NO EXAM
- For details, refer to lecture 1

Average to Letter Grade Mapping (Tentative)

Average	Letter Grade
< 60	F
60 – 64	C
65 – 69	C+
70 – 74	B-
75 – 79	B
80 – 84	B+
85 – 89	A-
90 – 94	A
>= 95	A+

Differences to ENSC 453 (cross-listed with ENSC 845)

The course outline is the same. Here is a list of Different Expectations/Evaluations for Undergraduate and Graduate Students, which I included when I created ENSC 453 (cross-listed with ENSC 845). Basically, graduate students are required to master some of the advanced topics which are not required for undergraduate students. More concretely,

- In the CPU lab assignments, graduate students are required to work on the advanced hierarchical tiling optimization.
- In the FPGA lab assignments, graduate students are required to work on advanced memory coalescing optimization.
- In the final project, graduate students are required to study quantitative comparison between FPGA and GPU implementations.
- In the paper presentation, graduate students will focus on the more difficult FPGA optimization papers.
- Undergraduate and graduate students grading criteria will be different as specified above.

Textbook(s) and reference material

OpenMP for multicore CPU:

- OpenMP Tutorial: https://hpc-tutorials.llnl.gov/openmp/
- OpenMP Specifications: https://www.openmp.org/specifications/
- OpenMP Examples: https://github.com/OpenMP/Examples.git
- OpenMP in Visual C++: http://msdn.microsoft.com/en-us/library/tt15eb9t.aspx

HLS C/C++ for FPGA:

- HLS user guide (Section II: Vitis HLS Methodology Guide): https://docs.xilinx.com/r/2020.2-English/ug1399-vitis-hls/Vitis-HLS-Methodology-Guide
- HLS pragma reference: https://docs.xilinx.com/r/2020.2-English/ug1399-vitis-hls/HLS-Pragmas
- HLS examples: https://github.com/Xilinx/Vitis-HLS-Introductory-Examples
- Vitis Document: https://docs.xilinx.com/r/2020.2-English/ug1393-vitis-application-acceleration
- Vitis Examples:
    - https://github.com/Xilinx/Vitis-Tutorials
    - https://github.com/Xilinx/Vitis_Accel_Examples
- OpenCL C++ Bindings: https://github.khronos.org/OpenCL-CLHPP/namespacecl.html
- Best-Effort FPGA Programming: https://arxiv.org/abs/1807.01340
- Rodinia-HLS Step-by-Step Code Examples: https://github.com/SFU-HiAccel/rodinia-hls

CUDA C/C++ for GPU:

- CUDA C++ Programming Guide: https://docs.nvidia.com/cuda/cuda-c-programming-guide/index.html
- CUDA examples: https://github.com/nvidia/cuda-samples
- David B. Kirk, Wenmei Hwu. “Programming Massively Parallel Processors”. A Hands-on Approach, 3rd Ed.
- GPU Computing Gems, Jade Edition and Emerald Edition
- More CUDA resources: https://developer.nvidia.com/how-to-cuda-c-cpp

Other references:

- Always Google first
- C++ Reference: http://www.cplusplus.com/reference/
- Stack overflow: https://stackoverflow.com/

SFU GRADUATE STUDIES

NEW GRADUATE COURSE PROPOSAL

Course Subject (eg. PSYC) ENSC	**Number** (eg. 810) 871	**Units** (eg. 4) 3

Course title (max. 100 characters) Optical and laser engineering applications

Short title (for enrollment/transcript - max 30 characters) Opt. Laser Eng. Appl.

Course description for SFU Calendar *(course descriptions should be brief and should never begin with phrases such as "This course will..." or "The purpose of this course is..." If the grading basis is satisfactory/unsatisfactory include this in the description. Max. 50 words)

A practical, hands-on exploration of optical engineering and lasers. Covers the concepts of light, optics (geometric optics, Gaussian optics, multiple optical elements, lens aberrations), laser concepts, operational details of major laser types, laser interactions with optical systems, laser applications in engineering and medicine, complex optical system design and fiber optics. Labs cover optical systems, lasers measurements, optical CAD design, holography.

Rationale for introduction of this course

This course was previously listed as ENSC 894 - Special Topics II. We would like to convert this from a Special Topics course into a regular graduate level course.

Term of initial offering (eg. Fall 2019)	Spring 2025	**Course delivery** (eg 3 hrs/week for 13 weeks)	Lecture: 3hrs/wk, Tutorial: 1hr/wk, 13wk , Lab: 2hrs/wk for 3 weeks
Frequency of offerings/year	Once per year	**Estimated enrollment per offering**	15 students

Equivalent courses (courses that replicates the content of this course to such an extent that students should not receive credit for both courses)

ENSC 470. Students with credit for ENSC 894 under the title "Optical Engineering and Laser Applications" may not take this course for further credit.

Prerequisite and/or Corequisite

None

Criminal record check required? ☐ Yes (if yes is selected, add this as prerequisite) **Additional course fees?** ☐ Yes ☑ No

Campus where course will be taught ☑ Burnaby ☐ Surrey ☐ Vancouver ☐ Great Northern Way ☐ Off campus

Course Components* ☑ Lecture ☐ Seminar ☑ Lab ☐ Research ☐ Practicum ☐ Online ☑ Other: Tutorial

Grading Basis ☑ Letter grades ☐ Satisfactory or Unsatisfactory ☐ In Progress/Complete

Repeat for credit? ☐ Yes ☑ No	**Total repeats allowed?** _____	**Capstone course?** ☐ Yes ☑ No
Required course? ☐ Yes ☑ No	**Final exam required?** ☑ Yes ☐ No	**Repeat within a term?** ☐ Yes ☑ No

Combined with an undergrad course? ☑ Yes ☐ No If yes, identify which undergraduate course and what the additional course requirements are for graduate students:

ENSC 470. Graduate students complete an additional project.

* See important definitions on the curriculum website.

RESOURCES

If additional resources are required to offer this course, provide information on the source(s) of those additional resources.

Faculty member(s) who will normally teach this course Matthew Shawn Sederberg
Additional faculty members, space, and/or specialized equipment required in order to offer this course The lab component of the course will require existing equipment located in ASB 10878.

CONTACT PERSON

Academic Unit / Program Engineering Science	**Name (typically, Graduate Program Chair)** Mirza Faisal Beg, ENSC GPC Chair	**Email** enscgpcc@sfu.ca

ACADEMIC UNIT APPROVAL

☑ A course outline / syllabus is included

Non-departmentalized faculties need not sign

Department Graduate Program Committee Mirza Faisal Beg	**Signature**	Mirza Faisal Beg Digitally signed by Mirza Faisal Beg DN: c=CA, ou=ENSC, o=Simon Fraser University, cn=Mirza Faisal Beg, email=mfbeg@sfu.ca Date: 2024.02.23 12:26:42 -08'00'	**Date**	02/23/2024
Department Chair Cheng Li	**Signature**	Digitally signed by Cheng Li Date: 2024.03.12 23:32:01 -07'00'	**Date**	03/12/2024

FACULTY APPROVAL

The course form and outline must be sent by FGSC to the chairs of each FGSC (fgsc-list@sfu.ca) to check for an overlap in content

overlap check done? ☑ YES

This approval indicates that all the necessary course content and overlap concerns have been resolved. The Faculty/Academic Unit commits to providing the necessary resources.

Faculty Graduate Studies Committee (FGSC) Parvaneh Saeedi	**Signature**	Parvaneh Saeedi Digitally signed by Parvaneh Saeedi Date: 2024.04.02 11:45:01 -07'00'	**Date**

A library review will be conducted. If additional funds are necessary, Graduate Studies will contact the academic unit prior to SGSC.

SENATE GRADUATE STUDIES COMMITTEE APPROVAL

Senate Graduate Studies Committee (SGSC) Mary O'Brien	**Signature**	Mary Hea O'Brien	**Date** May 16, 2024

ADMINISTRATIVE SECTION (for Graduate Studies office only)

Course Attribute: _____
Course Attribute Value: _____
Instruction Mode: _____
Attendance Type: _____

If different from regular units:
Academic Progress Units: _____
Financial Aid Progress Units: _____

Simon Fraser University
SCHOOL OF ENGINEERING SCIENCE

ENSC 871 - Optical and Laser Engineering Applications

Instructor: Shawn Sederberg
Email: shawn_sederberg@sfu.ca
Office: ASB 8833
Online content: Canvas
Classroom: TBD
Teaching Assistant: TBD

Calendar Description: A practical, hands-on introduction to optical engineering and lasers. Covers the concepts of light, optics (geometric optics, Gaussian optics, multiple optical elements, lens aberrations), laser concepts, operational details of major laser types, laser interactions with optical systems, laser applications in engineering and medicine, complex optical system design and fiber optics. Labs cover optical systems, lasers measurements, optical CAD design, holography.

Communication: Announcements will be posted to Canvas. Therefore, you are required to either log on to Canvas or check your SFU email daily for updates. Normally, communication will be directed to the class as a whole and no response is required. However, if I do contact you individually, a timely response consistent with what would be expected in a professional engineering environment is expected. I will be available in my office for questions every Friday from 10:45 AM - 11:45 AM. I will be available on Zoom on Tuesdays from 1:00 PM - 2:00 PM. Zoom office hours link.

Lecture Format: The first 70 minutes of each session will be devoted to a lecture relevant to the course material. We will then take a 10 minute break. During the final 30 minutes, we will solve tutorial questions. Lecture slides and tutorial questions will be made available in advance. The complete tutorial solutions will be made available at the end of each week.

Textbook: This course is designed to be self-contained. The two textbooks listed below can be used to supplement the lecture materials. The first one (Optics) is optional. The second one (Laser Physics) is free to download and is mandatory.

Optics (5th Edition), Eugene Hecht, Pearson, 2015. ISBN: 9780133977226

- Hard copies available in the SFU Library

Laser Physics, Peter W. Milonni and Joseph H. Eberly, John Wiley & Sons, Inc., 2010. ISBN: 9780470387719

- Can be downloaded free of charge through the SFU Library

Technology Requirements: The technology requirements for successfully completing the course include a computer with basic office software, Matlab, and internet access.

Assignments: Five assignments will be distributed during the semester. Students are encouraged to collaborate on assignments. However, the assignment submitted by each student must be unique and reflect their own efforts. Each student is responsible for ensuring that their work is consistent with SFU's Academic Integrity policies.

Midterm Exam: The midterm exam will be closed-book and will take place in the normal lecture location at 10:30 AM on TBD. There will not be a make-up midterm exam. The weight of the midterm will be

shifted to the final exam for anyone who is unable to write the midterm due to challenging personal circumstances.

Final Exam: The final exam will be closed book. Its date and location will be announced later in the semester. In the event that a significant personal misfortune causes someone to miss the final exam, arrangements can be made to write a make-up final exam. **You are strongly encouraged to contact Dr. Sederberg as soon as you suspect that you may not be able to write the final exam, as this enables me to help you better.**

Labs: Three labs will complement the lecture material. Lab manuals will be made available on Canvas at least one week before the lab begins. You are required to find a group of 3 students before the first lab session. Due to limited space in the lab room (ASB 10878), only two groups will be able to complete the lab at a time. Each lab group will need to sign up for the lab sessions using an Excel spreadsheet. This will be done on a first-come, first-served basis.

Prior to completing the first lab, each group will also be required to sign up for a lab orientation session, which will include demonstrations of how to handle optical components and assemble optical systems. In accordance with SFU's laser safety policies, each student will also need to complete laser safety training before completing the first lab. This training will be provided during one of the tutorial sessions.

Each lab group should submit a single report for each lab. At the end of the semester you will have the opportunity to submit an evaluation of your group members' contributions to the completion of the labs, including your own. This evaluation will contribute 25% to your overall lab grade.

Graduate course project: You will be required to complete an project on a topic related to optics, lasers, or photonics that interests you. The project must contain a significant element of experimental work, numerical simulation, or design related to this topic. Topics can be as diverse as: "Modelling light scattering in biological tissue," "Design and optimization of a laser cavity based on Yb:YAG gain medium," or "Wavelength-division multiplexing in silicon photonic waveguides at telecommunications wavelengths." The topic should not be related to machine learning, artifical intelligence, or anything else with a significant computer science element. A report summarizing the project will be due on the final day of classes. A short presentation will be given to the class. The class will participate in peer evaluation of the presentations. **The content of these presentations could be the subject of final exam questions.** Additional details about this project will be made available on Canvas.

Tentative Course Schedule:

Session	Day	Date	Assignments	Labs	Lecture Topics	Reading
1	W	May 10			Course overview, Introduction to light	Optics Ch. 3
2	F	May 12				
3	W	May 17		Lab orientation, laser safety training	Reflection, refraction, lenses, mirrors	Optics Ch. 4-5
4	F	May 19				
5	W	May 24			Ray matrices, ray tracing, aberrations	Laser Phys. Ch. 7.2, Optics Ch. 6.2-6.3
6	F	May 26	A1 due			
7	W	May 31		Lab 1	Gaussian optics	Laser Phys. Ch. 7.4-7.8
8	F	June 2				
9	W	June 7			Optical resonators, modes	Laser Phys. Ch. 7.1-7.3
10	F	June 9	A2 Due			
11	W	June 14			Atomic levels, rate equations	Laser Phys. Ch. 3.1-3.7
12	F	June 16				
13	W	June 21		Lab 2	Gain	Laser Phys. Ch. 3.12, 4
14	F	June 23	A3 Due		Midterm	
15	W	June 28			Threshold, saturation	
16	F	June 30				
17	W	July 5			Types of lasers	Laser Phys. Ch. 11
18	F	July 7	A4 Due			
19	W	July 12		Lab 3	Mode-locking	Laser Phys. Ch. 6.6-6.11
20	F	July 14				
21	W	July 19			Laser applications	Laser Phys. Ch. 14
22	F	July 21	A5 Due			
23	W	July 26			Laser applications	Laser Phys. Ch. 14
24	F	July 28				
25	W	Aug 2			871 presentations	
26	F	Aug 4			Review	

Evaluation: The documents you submit for ENSC 871 will be graded by the course instructor and the TA. The following is a breakdown of the grading scheme that will be used:

Item	Weight
Assignments	10%
Labs	15%
Project	15%
Midterm Exam	20%
Final Exam	40%

Assignments must be submitted by 11:59 PM on the due date. **Late documents will be penalized 10% per day late (or part thereof).** If there is a time during the semester when a majority of the class is overwhelmed with other deadlines, I'm completely open to changing the due date as long as it's fair to the entire class.

Assignments and exams will receive a percentage grade. The following table provides the letter grade equivalencies that will be used:

Letter Grade	Definition	GPA	Percentage*
A+	Excellent Performance	4.33	$G \geq 95.0$
A		4.00	$90.0 \leq G < 95.0$
A-		3.67	$80.0 \leq G < 90.0$
B+	Good Performance	3.33	$70.0 \leq G < 80.0$
B		3.00	$65.0 \leq G < 70.0$
B-		2.67	$60.0 \leq G < 65.0$
C+	Satisfactory Performance	2.33	$55.0 \leq G < 60.0$
C		2.00	$50.0 \leq G < 55.0$
F	Unsatisfactory Performance	0.00	$G < 50.0$
N		0.00	
FD		0.00	

*The variable G represents the percentage grade assigned to a particular element of the course.

Academic Integrity: As with all courses at SFU, you are expected to follow proper citation and referencing practices in ENSC 871 (see the SFU Code of Academic Integrity and Good Conduct). This means that you must cite and reference the sources for any material that you have taken from journals, books, and websites in your assignments and lab reports.

The sources for short quotations, paraphrases, figures, and tables must be clearly cited in the text of the documents using the IEEE format. More lengthy material, such as copies of standards, should be placed in appendices which clearly indicate the source. Complete reference lists are also required.

Failure to follow proper citation and referencing practices will result in a grade of 0 for the specific document involved (as well as the requirement to revise and resubmit the document). Three infractions will result in a recommendation of an F for ENSC 871.

Discrimination: There is zero tolerance for discrimination of any kind at SFU, including any activies related to ENSC 871. The SFU guidelines for reporting an incident can be found here:

The Human Rights Policy [GP 18] - Simplified

Dr. Sederberg will support any student who is a victim of discrimination wherever possible in the process.

Simon Fraser University
SCHOOL OF ENGINEERING SCIENCE

ENSC 470 - Optical and Laser Engineering Applications

Instructor: Shawn Sederberg
Email: shawn_sederberg@sfu.ca
Office: ASB 8833
Online content: Canvas
Classroom:TBD
Teaching Assistant: TBD

Calendar Description: A practical, hands-on introduction to optical engineering and lasers. Covers the concepts of light, optics (geometric optics, Gaussian optics, multiple optical elements, lens aberrations), laser concepts, operational details of major laser types, laser interactions with optical systems, laser applications in engineering and medicine, complex optical system design and fiber optics. Labs cover optical systems, lasers measurements, optical CAD design, holography.

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Lecture/Tutorial sessions: The first 70 minutes of each session will be devoted to a lecture relevant to the course material. We will then take a 10 minute break. During the final 30 minutes, we will solve tutorial questions. Lecture slides and tutorial questions will be made available in advance. The complete tutorial solutions will be made available at the end of each week.

Textbook: This course is designed to be self-contained. The two textbooks listed below can be used to supplement the lecture materials. The first one (Optics) is optional. The second one (Laser Physics) is free to download and is mandatory.

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- Hard copies available in the SFU Library

Laser Physics, Peter W. Milonni and Joseph H. Eberly, John Wiley & Sons, Inc., 2010. ISBN: 9780470387719

- Can be downloaded free of charge through the SFU Library

Technology Requirements: The technology requirements for successfully completing the course include a computer with basic office software, Matlab, and internet access.

Assignments: Five assignments will be distributed during the semester. Students are encouraged to collaborate on assignments. However, the assignment submitted by each student must be unique and reflect their own efforts. Each student is responsible for ensuring that their work is consistent with SFU's Academic Integrity policies.

Midterm Exam: The midterm exam will be closed-book and will take place in the normal lecture location at 10:30 AM on TBD. In the event that a significant personal misfortune causes someone to miss the final

exam, you may choose to either take an oral format make-up exam or shift the weight of the midterm to the final exam.

Final Exam: The final exam will be closed book. Its date and location will be announced later in the semester. In the event that a significant personal misfortune causes someone to miss the final exam, arrangements can be made to write a make-up final exam. **You are strongly encouraged to contact Dr. Sederberg as soon as you suspect that you may not be able to write the final exam, as this enables me to help you better.**

Labs: Three labs will complement the lecture material. Lab manuals will be made available on Canvas at least one week before the lab begins. You are required to find a group of 3 students before the first lab session. Due to limited space in the lab room (ASB 10878), only two groups will be able to complete the lab at a time. Each lab group will need to sign up for the lab sessions using an Excel spreadsheet. This will be done on a first-come, first-served basis.

Prior to completing the first lab, each group will also be required to sign up for a lab orientation session, which will include demonstrations of how to handle optical components and assemble optical systems. In accordance with SFU's laser safety policies, each student will also need to complete laser safety training before completing the first lab. This training will be provided during one of the tutorial sessions.

Each lab group should submit a single report for each lab. At the end of the semester you will have the opportunity to submit an evaluation of your group members' contributions to the completion of the labs, including your own. This evaluation will contribute 25% to your overall lab grade.

Tentative Course Schedule:

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2	F	May 12				
3	W	May 17		Lab orientation, laser safety training	Reflection, refraction, lenses, mirrors	Optics Ch. 4-5
4	F	May 19				
5	W	May 24			Ray matrices, ray tracing, aberrations	Laser Phys. Ch. 7.2, Optics Ch. 6.2-6.3
6	F	May 26	A1 due			
7	W	May 31		Lab 1	Gaussian optics	Laser Phys. Ch. 7.4-7.8
8	F	June 2				
9	W	June 7			Optical resonators, modes	Laser Phys. Ch. 7.1-7.3
10	F	June 9	A2 Due			
11	W	June 14			Atomic levels, rate equations	Laser Phys. Ch. 3.1-3.7
12	F	June 16				
13	W	June 21		Lab 2	Gain	Laser Phys. Ch. 3.12, 4
14	F	June 23	A3 Due		Midterm	
15	W	June 28			Threshold, saturation	
16	F	June 30				
17	W	July 5			Types of lasers	Laser Phys. Ch. 11
18	F	July 7	A4 Due			
19	W	July 12		Lab 3	Mode-locking	Laser Phys. Ch. 6.6-6.11
20	F	July 14				
21	W	July 19			Laser applications	Laser Phys. Ch. 14
22	F	July 21	A5 Due			
23	W	July 26			Laser applications	Laser Phys. Ch. 14
24	F	July 28				
25	W	Aug 2			871 presentations	
26	F	Aug 4			Review	

Evaluation: The documents you submit for ENSC 470 will be graded by the course instructor and the TA. The following is a breakdown of the grading scheme that will be used:

Item	Weight
Assignments	15%
Labs	20%
Midterm Exam	25%
Final Exam	40%

Assignments must be submitted by 11:59 PM on the due date. **Late documents will be penalized 10% per day late (or part thereof).** If there is a time during the semester when a majority of the class is overwhelmed with other deadlines, I'm completely open to changing the due date as long as it's fair to the entire class.

Assignments and exams will receive a percentage grade. The following table provides the letter grade equivalencies that will be used:

Letter Grade	Definition	GPA	Percentage*
A+	Excellent Performance	4.33	$G \geq 95.0$
A		4.00	$90.0 \leq G < 95.0$
A-		3.67	$85.0 \leq G < 90.0$
B+	Good Performance	3.33	$80.0 \leq G < 85.0$
B		3.00	$75.0 \leq G < 80.0$
B-		2.67	$70.0 \leq G < 75.0$
C+	Satisfactory Performance	2.33	$65.0 \leq G < 70.0$
C		2.00	$60.0 \leq G < 65.0$
C-	Marginal Performance	1.67	$55.0 \leq G < 60.0$
D	Unsatisfactory Performance	1.00	$50.0 \leq G < 55.0$
F		0.00	$G < 50.0$

*The variable G represents the percentage grade assigned to a particular element of the course.

Academic Integrity: As with all courses at SFU, you are expected to follow proper citation and referencing practices in ENSC 470 (see the SFU Code of Academic Integrity and Good Conduct). This means that you must cite and reference the sources for any material that you have taken from journals, books, and websites in your assignments and lab reports.

The sources for short quotations, paraphrases, figures, and tables must be clearly cited in the text of the documents using the IEEE format. More lengthy material, such as copies of standards, should be placed in appendices which clearly indicate the source. Complete reference lists are also required.

Failure to follow proper citation and referencing practices will result in a grade of 0 for the specific document involved (as well as the requirement to revise and resubmit the document). Three infractions will result in a recommendation of an F for ENSC 470.

Discrimination: There is zero tolerance for discrimination of any kind at SFU, including any activies related to ENSC 470. The SFU guidelines for reporting an incident can be found here:

The Human Rights Policy [GP 18] - Simplified

Dr. Sederberg will support any student who is a victim of discrimination wherever possible in the process.

SFU GRADUATE AND POSTDOCTORAL STUDIES

New Graduate Course Proposal

Course Subject (eg. PSYC)	Number (eg. 810)	Units (eg. 4)
ENSC	875	4

Course title (max. 100 characters)

Biomedical Instrumentation

Short title (for enrollment/transcript - max. 30 characters) **BME INSTR**

Course description for SFU Calendar (course descriptions should be brief and should never begin with phrases such as "This course will..." or "The purpose of this course is..." If the grading basis is satisfactory/unsatisfactory include this in the description)

Instrumentation techniques for measuring common physiological signals. Bioelectric and biophysical sensors. Electronic design issues: electrical safety, signal conditioning and protection against noise, digital signal acquisition. Live subject ethical considerations. Laboratory work to include use of data acquisition packages in conjunction with various sensors, as well as design and construction of a full signal acquisition chain, from sensor to RAM.

Rationale for introduction of this course

The course has already been successfully run as a special topics graduate level course 6 times (2015, 2019 - 2023). It is cross-listed with ENSC 475 Biomedical Instrumentation.

Term of initial offering (eg. Fall 2019)	Course delivery (eg. 3 hrs/week for 13 weeks)
Spring 2025	LEC 3 hrs/wk for 13 weeks;TUT 1 hr/wk for 13 weeks;LAB 5 hrs for 13 weeks
Frequency of offerings/year: 1 time per year	Estimated enrollment per offering: 6

Equivalent courses (courses that replicates the content of this course to such an extent that students should not receive credit for both courses)
ENSC 475, ENSC 895* Special Topics III "ST-Biomedical Instrumentation". *ENSC 895 ST courses with other titles/ descriptions should not be considered equivalent.

Prerequisite and/or Corequisite: permission of instructor

Criminal record check required? ☐ Yes if yes is selected, add this as prerequisite

Additional course fees? ☐ Yes ☑ No

Campus where course will be taught: ☑ Burnaby ☐ Surrey ☐ Vancouver ☐ Great Northern Way ☐ Off campus

Course Components *: ☑ Lecture ☐ Seminar ☑ Lab ☐ Independent ☐ Capstone ☑ Tutorial

Grading Basis: ☑ Letter grades ☐ Satisfactory/ Unsatisfactory ☐ In Progress / Complete

Repeat for credit? ☐ Yes ☑ No

Total repeats allowed? _____

Repeat within a term? ☐ Yes ☑ No

Required course? ☐ Yes ☑ No

Final exam required? ☐ Yes ☑ No

Capstone course? ☐ Yes ☑ No

Combined with a undergrad course? ☑ Yes ☐ No If yes, identify which undergraduate course and the additional course requirements for graduate students:
ENSC 475; additional graduate requirements are to design a new lab experiment based on course content

* See important definitions on the curriculum website.

RESOURCES

If additional resources are required to offer this course, provide information on the source(s) of those additional resources.

Faculty member(s) who will normally teach this course
Bonnie Gray
Additional faculty members, space, and/or specialized equipment required in order to offer this course
Ash Parameswaran; Andrew Rawicz; the lab is held jointly with the existing ENSC 475 lab

CONTACT PERSON

Academic Unit / Program	Name (typically, Graduate Program Chair)	Email
Engineering Science	Faisal Beg	enscgpcc@sfu.ca

ACADEMIC UNIT APPROVAL

A course outline must be included.

Non-departmentalized faculties need not sign

Graduate Program Committee	Signature	Date
Mirza Faisal Beg	Digitally signed by Mirza Faisal Beg DN: cn=Mirza Faisal Beg, o=Simon Fraser University, ou=School of Engineering Science, email=mfbeg@sfu.ca, c=US Date: 2023.10.01 01:15:54 -07'00'	
Department Chair	**Signature**	**Date**
Cheng Li		2023-10-03

FACULTY APPROVAL

The course form and outline must be sent by FGSC to the chairs of each FGSC (fgsc-list@sfu.ca) to check for an overlap in content

Overlap check done? ☑ YES

This approval indicates that all the necessary course content and overlap concerns have been resolved. The Faculty/Academic Unit commits to providing the necessary resources.

Faculty Graduate Studies Committee	Signature	Date
Parvaneh Saeedi		Oct 26, 2023

A library review will be conducted. If additional funds are necessary, DGS will contact the academic unit prior to SGSC.

SENATE GRADUATE STUDIES COMMITTEE APPROVAL

Senate Graduate Studies Committee	Signature	Date

ADMINISTRATIVE SECTION (for DGS office only)

Library Check: _____
Course Attribute: _____
Course Attribute Value: _____
Instruction Mode: _____
Attendance Type: _____

If different from regular units:
Academic Progress Units: _____
Financial Aid Progress Units: _____

ENSC 475/875: Biomedical Instrumentation

Sample Course Outline

Please note that it will be assumed that you have read this course outline in its entirety and are aware of the course policies set forth in it including course attendance, homework, lab, and exam policies. If you have an administrative question, *look here first*; it is probably already answered!

Course description
This course covers instrumentation techniques for measuring common physiological signals, including: bioelectric and biophysical sensors; electronic design issues: electrical safety, signal conditioning, protection against noise, and digital signal acquisition; and live subject ethical considerations. Practical assignment work includes use of data acquisition and design of various sensors, as well as design and construction of a signal acquisition chain for commonly employed biomedical sensors and data interpretation.

Learning outcomes
This course covers the essentials of biomedical instrumentation and enables students to apply engineering principles to the measurement and interpretation of biological signals. Upon successful completion of this course, students will be able to:

1. Identify and understand common biomedical engineering discipline-specific electronics, sensors, and signal conditioning.
2. Design, build and test circuits that capture physiological signals such as temperature, bioelectric, and blood flow measurements.
3. Discuss electrical design issues relating to signal conditioning of physiological signals.
4. Discuss safety and electrical safety issues relating to measurement from live subjects.
5. Discuss the principal and operation of various common biomedical instruments, that may include: cardiographs, pulse oximeters, non-invasive blood pressure (NIBP) monitors, temperature monitors.
6. Have rudimentary understanding of medical device standards, regulatory environment, design control, and risk management.
7. Analyze methods used for design input/output and critically evaluate medical device designs; evaluate data obtained from such instruments.
8. Work individually and as a team on medical device development.

Prerequisite:
Please note that biomedical option undergraduate students (for whom ENSC 475 is required) have priority for admission to the class.
For all students: Students with credit for historic course ENSC 372 cannot take this course for further credit. Prerequisites: (ENSC 225 or MSE 251), ENSC 320, (ENSC 380 or MSE 280) and a minimum of 80 units. ENSC 380/MSE 280 can be taken concurrently. NO EXCEPTONS.
Additional requirement for *electronic* and *computer engineering* undergraduate students: A minimum of 90 credit hours.
Graduate students: Instructor permission.

Course meeting times
TBD
Tutorial will normally be held the second hour of the second offering per week

Instructor

Dr. Bonnie Gray Email: bgray@sfu.ca
Office: room TBA for in person OH, and remote OH via *Zoom*
Office Hours (OH): 1 hour in person plus remote 1 hour per week time TBA

Teaching Assistant

TBA

Course website

Online course content will be handled using CANVAS. Please check the site frequently for information, handouts, etc., assignments, labs, and notes postings, and to sign up for lab groups. In person course meetings will be recorded; any remote instruction will be.

Required course texts

"Medical Instrumentation Application and Design" (5th Edition), John G. Webster, Wiley, 2020. ISBN: 978-1119457336. Available in the SFU Bookstore. You may use prior versions of the textbook at your own risk.

Grading

Undergraduate Students:

Homework	10%
Labs	30%
Midterm exam	20%
Final exam	40%

Graduate Students:

Homework	10%
Labs	30%
Midterm exam #1	20%
Midterm exam #2	20%
New lab design	20%

There are no alternate grading schemes available. Assignments or exams for re-grade will only be accepted up to 1 week after they are returned, with the *entire assignment/exam* re-graded and your score could go down.

Class and exam attendance

You must attend classes to get essential information for passing the course and for the labs. You are responsible for all activities conducted during the scheduled class period, including any announcements given. *No exceptions to this will be made if you miss or are late to class.*

In person exams will be closed book/notes with formula sheets provided (posted before the exam). The 90 minute **midterm(s)** will be handled in person (if allowed). If SFU switches to remote exams, the timing and nature of the exam may change. The **second graduate student midterm** will be held during the first 90 minutes of the 180 minute undergraduate final exam slot (see below).

The **final exam** for undergraduates will be held during the **3 hour** time slot **TBA** by the registrar (check gosfu). The final exam will also be held in person or remotely depending on SFU policy at the time. The final exam will cover the entire course with more emphasis on material covered after the midterm. *The final exam will be cumulative and will include both final exam and midterm 2 material*

(no formal second midterm, with more emphasis on the final exam for material not covered on the midterm; this will be discussed in more detail near the end of the course).

Failure to take an exam during the assigned period will result in a grade of zero being recorded unless you have personally contacted Dr. Gray BEFORE the exam. Your reasons must be seriously medical (with valid doctor's medical excuse form filled out per SFU templates) or bereavement as determined by SFU policies. Please be advised that although every effort is made to make make-up exams of a similar difficulty level to the original exam, this is very difficult to do and there are no guarantees, and *generally the make-up will be the same level or more difficult*.

Homework policy

Homework assignments will be distributed 1-2 weeks prior to the due date via the web site. Completed assignments must be submitted online via Canvas on the due date or your assignment will be considered late. Late assignments can be submitted, but only up until the following day with a 50% penalty. After this time the late assignment will not be graded and will receive a zero. This policy will be strictly adhered to; it is to ensure that answer keys can be distributed to on-time students in a timely fashion and to be fair to students who submit timely assignments. Only legible assignments will be graded, and only a portion of the assignments will be graded. Please also note that although homework questions are intended to reinforce the major concepts and to serve as a learning tool, they are not necessarily representative of questions that will be asked on the exams.

Labs

Practical experience is an essential part of this course. There are 3 labs that emphasize practical aspects of course content. You must work in groups of the specified size (typically 3 or 4 persons) and submit one report for your group. Please note that in the case of the class numbers not allowing equally-sized groups (or group members dropping the class), groups of all sizes will be treated the same with no allowances for potential work load differences. You must sign up for a lab group or you will be assigned randomly to a group. Group sign up will be via CANVAS. Graduate students are typically assigned to their own lab group. Please check the CANVAS course site for information on signing up for lab groups.

Your report must be limited to the number of pages specified on each lab guide. Additional pages will be disregarded. *You must include the filled out lab guide with your* report; these pages do not count toward the page limit. Lab reports are due on the due date via CANVAS submission. This deadline will be strictly adhered to or a penalty of 50% will be assigned for each day/part of a day that the assignment is late.

If SFU switches to all remote instruction, then labs will be replaced with related practical assignments that will carry the same weight for the overall grade.

Graduate student lab design

Graduate students will design a lab guide similar to that of exiting Labs 1, 2 and 3 for a laboratory experiment of their own choosing. The design can be a paper design without actually building the circuit; however, circuit design, safety, and numerical circuit analysis must be performed, and all components for a student "kit" identified that would be purchased if the laboratory were to be built and tested. The designed lab should utilized equipment already available in the course laboratory. Example laboratories: 1) electrode-based circuit for EOG (eye position measurement); 2) medical pressure sensors with Wheatstone bridge read-out; 3) piezoelectric sensor and read-out for pulse measurement; 4) simple negative capacitance amplifier for micropipette electrodes.

ENSC 475/875 Tentative syllabus

Lecture	Topics/Reading assignment	Tutorial	DUE/notes
Day 1	Chap 1,2		
Day 2	Chap 1,2		
Day 3	Chap 1,2	Chap 1,2	
Day 4	Chap 1,2		
Day 5	Chap 3	Chap 2	
Day 6	Chap 3		HW1 due
Day 7	Chap 3	Chap 3	
Day 8	Chap 4		HW 2 due
Day 9	Chap 4	Chap 4	
Day 10	Chap 4,5		
Day 11	Chap 5	Chap 4,5	
Day 12	Chap 5		Lab1 due
Day 13	Chap 6	Chap 5	
Day 14	Chap 6		HW 3 due
Day 15	Chap 6	Chap 6	
Day 16	**MIDTERM 10:45AM-12:15PM** (coverage: Chap 1-5; Hw 1,2,3; Lab 1)		
Day 17	Chap 6,	Chap 6	
Day 18	Chap 7		Lab 2 due
Day 19	Chap 7	Chap 7	
Day 20	Chap 8,10		
Day 21	Chap 10	Chap 8/10	HW4 due
Day 22	Chap 14		
Day 23	Chap 14	Chap 14	
Day 24	Chap 14		Lab3 due
Day 25	BME: Reg&Legal	Chap 14, Reg&Legal	
Day 26	BME: Reg&Legal		HW5 due
TBA	**FINAL EXAM (Ugrad) or MIDTERM 2 (grad)**		TBA

Chapter by chapter content:

Chap 1: Introductory material and high level design considerations (generalized sensor systems; 1st & 2nd order systems; sensitivity; input impedance; signal conditioning; static and dynamic characteristics)
Chap 2: Sensors (displacement; strain; force; temperature; optical)
Chap 3: Circuits for biomedical devices including op-amps; instrumentation amps; non-idealities; basic filters; optical component circuitry; sensor read-out circuitry.
Chap 4: Biopotentials; action potentials and propagation; reflex arc; specific bioelectric signals (heart; neuro; muscle; eye position; retina; EEG)
Chap 5: Electrodes; half-cell potentials; non-polarizable electrodes; electrode electrical models; microelectrodes; electrode arrays
Chap 6: Biopotential amplifiers; heart dipole; Wilson's central terminal; Eindhoven's triangle; electrode placements and ECG leads; ECG basics; electromagnetic noise models; common mode signal interference and solutions; shielding; right leg drive; micropipette electrodes; EEG amplifies
Chap 7: Blood pressure wave and measurement; electric-fluid analog models; automated systems.
Chap 8, 10: Blood flow measurement; cardiac output; ultrasound; plethysmography; pulse oximetry.
Chap 14: Electrical safety; macro and micro shock; proper grounding; ground faults; isolation transformers and other shock hazard mitigation techniques.
Chap 15: Introduction to standards and codes; risk analysis techniques; medical device classification; regulatory body approval.

SFU GRADUATE STUDIES

NEW GRADUATE COURSE PROPOSAL

Course Subject (eg. PSYC) ENSC	**Number** (eg. 810) 884	**Units** (eg. 4) 3

Course title (max. 100 characters) Robotics: Motion and Control I

Short title (for enrollment/transcript - max 30 characters) Robotics: Motion and Control I

Course description for SFU Calendar *(course descriptions should be brief and should never begin with phrases such as "This course will..." or "The purpose of this course is..." If the grading basis is satisfactory/unsatisfactory include this in the description. Max. 50 words)

Fundamentals of robotics: mathematical representation of kinematics, dynamics and control. Planning and execution of robot trajectories. Feedback from the environment: use of sensors and machine vision. A brief introduction to robot languages. Different application domains for manipulator robots, e.g., assembly, manufacturing, etc.

Rationale for introduction of this course

This will be a cross-listed graduate course with ENSC 488.

Term of initial offering (eg. Fall 2019)	Spring 2025	**Course delivery** (eg 3 hrs/week for 13 weeks)	3hrs/LEC and 1hr/TUT for 13 weeks; Open Lab
Frequency of offerings/year	once per year	**Estimated enrollment per offering**	5-10

Equivalent courses (courses that replicates the content of this course to such an extent that students should not receive credit for both courses)

ENSC 488

Prerequisite and/or Corequisite

Recommended prerequisite(s): a basic control course (ENSC 383) and a basic mechanics course

Criminal record check required? ☐ Yes (if yes is selected, add this as prerequisite) | **Additional course fees?** ☐ Yes ☑ No

Campus where course will be taught ☑ Burnaby ☐ Surrey ☐ Vancouver ☐ Great Northern Way ☐ Off campus

Course Components* ☑ Lecture ☐ Seminar ☑ Lab ☐ Research ☐ Practicum ☐ Online ✓ Other: Tutorial

Grading Basis ☑ Letter grades ☐ Satisfactory or Unsatisfactory ☐ In Progress/Complete

Repeat for credit? ☐ Yes ☑ No	**Total repeats allowed?** _____	**Capstone course?** ☐ Yes ☑ No
Required course? ☐ Yes ☑ No	**Final exam required?** ☑ Yes ☐ No	**Repeat within a term?** ☐ Yes ☑ No

Combined with an undergrad course? ☑ Yes ☐ No If yes, identify which undergraduate course and what the additional course requirements are for graduate students:

ENSC 488; Graduate students will do a more extensive project and/or read litearature in a sub-area of manipulator robotics

* See important definitions on the curriculum website.

RESOURCES

If additional resources are required to offer this course, provide information on the source(s) of those additional resources.

Faculty member(s) who will normally teach this course
Kamal Gupta, Shahram Panyandeh, Mike Hegedus
Additional faculty members, space, and/or specialized equipment required in order to offer this course
Will use already available equipment and lab for ENSC 488.

CONTACT PERSON

Academic Unit / Program	**Name (typically, Graduate Program Chair)**	**Email**
Engineering Science	Mirza Faisal Beg	enscgpcc@sfu.ca

ACADEMIC UNIT APPROVAL

☑ A course outline / syllabus is included

Non-departmentalized faculties need not sign

Department Graduate Program Committee Mirza Faisal Beg	**Signature**	Mirza Faisal Beg Digitally signed by Mirza Faisal Beg DN: cn=Mirza Faisal Beg, o=Simon Fraser University, ou=School of Engineering Science, email=mfbeg@sfu.ca, c=US Date: 2024.02.22 16:03:31 -08'00'	**Date**	02/22/2024
Department Chair Cheng Li	**Signature**	Digitally signed by Cheng Li Date: 2024.02.23 17:27:06 -08'00'	**Date**	02-23-2024

FACULTY APPROVAL

The course form and outline must be sent by FGSC to the chairs of each FGSC (fgsc-list@sfu.ca) to check for an overlap in content

overlap check done? ☑ YES

This approval indicates that all the necessary course content and overlap concerns have been resolved. The Faculty/Academic Unit commits to providing the necessary resources.

Faculty Graduate Studies Committee (FGSC)			
Parvaneh Saeedi	**Signature**	Parvaneh Saeedi Digitally signed by Parvaneh Saeedi Date: 2024.04.02 11:46:11 -07'00'	**Date**

A library review will be conducted. If additional funds are necessary, Graduate Studies will contact the academic unit prior to SGSC.

SENATE GRADUATE STUDIES COMMITTEE APPROVAL

Senate Graduate Studies Committee (SGSC)			
Mary O'Brien	**Signature**		**Date** May 16, 2024

ADMINISTRATIVE SECTION (for Graduate Studies office only)

Course Attribute: _____
Course Attribute Value: _____
Instruction Mode: _____
Attendance Type: _____

If different from regular units:
Academic Progress Units: _____
Financial Aid Progress Units: _____

ENSC-488/884

Robotics: Motion and Control I

The course broadly covers basic issues in planning and control of robot motion, focusing particularly on manipulator robots, also called robotic arms. The attempt is to cover fundamental analytical and algorithmic techniques. We will cover the following:

- Introduction -- Basic terminology and preview of topics
- Mathematical representation of rotations and translations: homogeneous transformations
  - Interpretation of homogeneous matrices as co-ordinate frames
  - Relative Transformations
  - Transform Equations
  - Various Representations of Orientation
- Kinematics of Robot arm
  - Denavit and Hartenberg Notation
  - Forward and Inverse Kinematics
  - Closed form and numerical iterative solutions for Inverse Kinematics
  - Examples of Common Industrial Manipulators

Midterm I: will likely cover material up to and including Forward Kinematics. In class. Duration 1.5 hrs.

- Differential Motion and Statics
  - Linear and angular velocity of rigid bodies
  - Determining velocities of robot links
  - Jacobians
  - Singularities
  - Static force/torque relationships
- Path and Trajectory Planning
  - Basic path planning concepts: configuration space, potential fields and probabilistic sampling methods.
  - Trajectory planning: general considerations
  - Interpolated motion
  - Cartesian space vs. joint space motion

Midterm II: will likely cover material up to and including Differential Motion. In class. Duration 1.5 hrs.

- Dynamics and Control of a robot arm
  - Forward and Inverse Dynamics
  - Newton-Euler Formulation of equations of motion
- Some Control Strategies:
  - Computed Torque and Resolved Motion Control
  - Real time computational issues
- Robot Programming and Task Level Planning (time permitting)

- A classification of different types of robot programming languages.
- Issues in Task level Planning
- World modelling: geometric representation of objects
- Configuration space: representation and search
- Collision avoidance and path planning, etc.

Assignments: There will be about six assignments in all, roughly one every two weeks. Each assignment will have exercises and some programming component that applies the learned material to a 4-link SCARA manipulator and leads to your project demos (See below under Project ROBSIM).

Midterm(s): Duration: 1.5 hours.

- Closed book. One double sided crib sheet allowed for midterm 1 and two double sided crib sheets allowed for midterm 2. Only formulas/procedures are allowed. No solved examples/derivations/proofs on the crib sheet.
- Only Scientific calculators are allowed.

Final: Duration 2.5 hours.

- Closed book. Three double sided crib sheets allowed. Only formulas/procedures are allowed. No solved examples/proofs are allowed on the crib sheets.
- A basic scientific calculator is allowed.
- Material:
  - All material in Midterm(s) as mentioned above.
  - All Lectures

Project ROBSIM:

The default project ROBSIM is built around a 4-DOF SCARA robot. Two such robots are located in the the temporary (because of ongoing construction) Lab ASB 9896 (shared with ENSC 350).You will gradually build the code for the project via programming assignments during the course. Therefore, by the end of the course, you will have gradually built an entire library of robot motion (planning and control) software. This will be used for the project and will be demonstrated both on the real SCARA robots in the lab as well as on an in-house written graphical simulator, which will be provided to you. More details to be posted. You also have a choice to define or choose a project of your own. Students interested in doing so are encouraged to contact me early in the semester.

Text:

- *Introduction to Robotics: Mechanics and Control* by John J. Craig. Latest edition. Pearson Prentice Hall. `2 hr reserve at the Library.` You can also use an older edition (the material covered is the same), however, for questions in the assignments you will need to refer to the latest edition, since the problem numbers at the end of the chapters may vary from edition to edition.

Reference:

- *Foundations of Robotics* by Tsuneo Yoshikawa. MIT Press. 2 hr reserve at the Library.
- *Robot Modeling and Control* by Spong, Hutchinson, and Vidyasagar. John Wiley & Sons. 2 hr reserve at the Library.

Software Tools:

- C/C++, Maple/Mathematica, MATLAB and OpenGL.

Evaluation

- Assignments -- 10%
- Midterm(s) -- 25%
- Final -- 35%
- Class Project -- 30%

Prerequisites:

Students should have a basic knowledge of Linear Algebra, Differential Equations, Basic Feedback Control, Numerical Analysis, Basic Mechanics, and familiarity with a high level programming language (preferably C/C++).

Differences in Evaluation Between 488 and 884
31 January, 2024

The course has a project component to it. ENSC 884 students are required to do the following in addition to what the undergraduate students do in ENSC 488.

1. An additional component is added to the course project for 884 students, and/or
2. Additional reading of some current papers followed by a report is required for 884 students.

Details may vary from instructor to instructor. For instance, the current instructor (2024-1 offering) does the following for the graduate course:

1) Students are asked to pick a Cartesian planner to complete in the project and include it in the report, Or pick a Force Closure algorithm to complete and include it in the report.

2) 1 journal paper about force closure is assigned to review/summarize in Feb. In March, grad students (mandatory participation) meet the instructor, and they have a round table discussion about the journal paper. In that discussion, all MATLAB functions are given to them as well as pseudo code to implement the algorithm. (Marks for discussion + summary + participation)

3) A short report is due to visualize/evaluate their algorithm from provided test cases.

Students have options to pursue other projects relating to robotics. They can also suggest papers of their own interest to the instructor. Generally, they are asked to keep the project within mechanics/robotics and away from machine learning (unless mechanics is involved).

Instructors: Kamal Gupta/Mike Hegedus/Shahram Payandeh

OFFICE OF THE DEAN
Faculty of Applied Sciences
Simon Fraser University

MEMORANDUM

Attention Dr. Mary O'Brien
Vice-provost and Dean, Graduate Studies

Date: Nov 17, 2023

From Dr. Parvaneh Saeedi, psaeedi@sfu.ca
Faculty of Applied Science, Graduate Studies Committee

Re: FAS- New MSE Graduate Course Proposals – MSE 753 and 754

The faculty of Applied Sciences Graduate Studies Committee would like to propose two new graduate courses Hybrid Thermal Electric Microgrids 1 and Hybrid Thermal Electric Microgrids 2. The rationale for these courses is that they are a required part of the curriculum associated with the approved NSERC CREATE program led by Dr. Majid Bahrami. Previously, they were offered as special topics courses twice, allowing Dr. Bahrami and the instructional team to fine-tune the syllabus and content.

SFU doesn't offer a similar course. No pre-requisites are required for this course, allowing students from various disciplines outside MSE to join. It's attractive for those in the NSERC CREATE program and other mechatronics students alike. Expanding our graduate course offerings to include broad and interdisciplinary topics like these two Hybrid Thermal Electric Microgrid courses will help prepare our graduate students for jobs in this rapidly growing area.

FGSC has approved these items. I request you to kindly place these on the agenda for the next SGSC meeting.

Parvaneh Saeedi,
Associate Dean, Research and Graduate Studies
Faculty of Applied Sciences

SFU FACULTY OF APPLIED SCIENCES | SCHOOL OF MECHATRONIC SYSTEMS ENGINEERING

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MEMORANDUM

Date: October 18, 2023
To: Dr. Parvaneh Saeedi, FAS Associate Dean of Research
From: Dr. Carolyn Sparrey, Chair, Graduate Program Committee, Mechatronic Systems Engineering

Re: New Graduate Courses – Hybrid Thermal Electric Microgrids 1 and 2

The School of Mechatronic Systems Engineering would like to propose two new graduate courses Hybrid Thermal Electric Microgrids 1 and Hybrid Thermal Electric Microgrids 2. The rationale for these courses is that they are a required part of the curriculum associated with the approved NSERC CREATE program led by Dr. Majid Bahrami. These courses have been offered twice as special topics courses, providing the opportunity for Dr. Bahrami and the instructor team to refine the syllabus and content.

There is no similar course offered at SFU. The course has no pre-requisites in order to provide opportunities for students outside of MSE to participate. This course is of interest to students within the NSERC CREATE program as well as many other mechatronics students.

Expanding our graduate course offerings to include broad and interdisciplinary topics like these two Hybrid Thermal Electric Microgrid courses will help prepare our graduate students for jobs in this rapidly growing area.

X_____

Carolyn Sparrey
Graduate Program Chair, School of Mechatronic Systems Engineering

SFU GRADUATE STUDIES

NEW GRADUATE COURSE PROPOSAL

Course Subject (eg. PSYC) MSE	**Number** (eg. 810) 753	**Units** (eg. 4) 3

Course title (max. 100 characters) Hybrid Thermal Electric Microgrids I

Short title (for enrollment/transcript - max 30 characters) Hybrid Microgrids I

Course description for SFU Calendar *(course descriptions should be brief and should never begin with phrases such as "This course will..." or "The purpose of this course is..." If the grading basis is satisfactory/unsatisfactory include this in the description. Max. 50 words)

Covers hybrid microgrids with strong practical training components. Topics include i) hybrid microgrid concepts, modeling and analysis; ii) energy storage and conversion technologies; iii) distributed energy resources; iv) energy policy; v) lean entrepreneurship; vi) microgrid management, control and stability. Part one of a 2-part project-oriented graduate course.

Rationale for introduction of this course

There is a need for a holistic training that covers engineering as well as business, techno-economical, environmental, social (engagement, awareness, acceptance, participation), and policymaking aspects of emerging sustainable energy grids.

Term of initial offering (eg. Fall 2019) Spring 2025	**Course delivery** (eg 3 hrs/week for 13 weeks) 3 hrs/week for 13 weeks
Frequency of offerings/year yearly	**Estimated enrollment per offering** 20

Equivalent courses (courses that replicates the content of this course to such an extent that students should not receive credit for both courses)

MSE 453

Prerequisite and/or Corequisite

None

Criminal record check required? ☐ Yes (if yes is selected, add this as prerequisite) | **Additional course fees?** ☐ Yes ☑ No

Campus where course will be taught ☐ Burnaby ☑ Surrey ☐ Vancouver ☐ Great Northern Way ☐ Off campus

Course Components* ☑ Lecture ☐ Seminar ☐ Lab ☐ Research ☐ Practicum ☐ Online Other:

Grading Basis ☑ Letter grades ☐ Satisfactory or Unsatisfactory ☐ In Progress/Complete

Repeat for credit? ☐ Yes ☑ No	**Total repeats allowed?** none	**Capstone course?** ☐ Yes ☑ No
Required course? ☐ Yes ☑ No	**Final exam required?** ☐ Yes ☑ No	**Repeat within a term?** ☐ Yes ☑ No

Combined with an undergrad course? ☑ Yes ☐ No If yes, identify which undergraduate course and what the additional course requirements are for graduate students:

MSE 453
Graduate students must do additional work including: presentations for the entrepreneurial modules and case study reports for the thermal grid module.

* See important definitions on the curriculum website.

RESOURCES

If additional resources are required to offer this course, provide information on the source(s) of those additional resources.

Faculty member(s) who will normally teach this course Majid Bahrami (SFU), Terri Griffith (SFU), Canizares (Waterloo), Cruickshank (Carleton), Lau (UBC), Mallet (Carleton)
Additional faculty members, space, and/or specialized equipment required in order to offer this course None.

CONTACT PERSON

Academic Unit / Program MSE	**Name (typically, Graduate Program Chair)** Carolyn Sparrey	**Email** csparrey@sfu.ca

ACADEMIC UNIT APPROVAL

☑ A course outline / syllabus is included

Non-departmentalized faculties need not sign

Department Graduate Program Committee Carolyn Sparrey	**Signature**	**Date** Dec 20, 2023
Department Chair John Zheng Shen	**Signature** John Shen Digitally signed by John Shen Date: 2023.12.20 09:34:27 -08'00'	**Date** Dec 20, 2023

FACULTY APPROVAL

The course form and outline must be sent by FGSC to the chairs of each FGSC (fgsc-list@sfu.ca) to check for an overlap in content

overlap check done? ☑ YES

This approval indicates that all the necessary course content and overlap concerns have been resolved. The Faculty/Academic Unit commits to providing the necessary resources.

Faculty Graduate Studies Committee (FGSC) Parvaneh Saeedi	**Signature**	**Date** Dec 20, 2023

A library review will be conducted. If additional funds are necessary, Graduate Studies will contact the academic unit prior to SGSC.

SENATE GRADUATE STUDIES COMMITTEE APPROVAL

Senate Graduate Studies Committee (SGSC) Mary O'Brien	**Signature**	**Date** May 16, 2024

ADMINISTRATIVE SECTION (for Graduate Studies office only)

Course Attribute: _____
Course Attribute Value: _____
Instruction Mode: _____
Attendance Type: _____

If different from regular units:
Academic Progress Units: _____
Financial Aid Progress Units: _____

Course Title: Hybrid Thermal Electric Microgrids 1

Course Times: <TBD>
Instructor: Majid Bahrami
Delivery Method: Remote
Prerequisites: none

Calendar Description
This course covers hybrid microgrids with strong practical training components. Topics include i) hybrid microgrid concepts, modeling and analysis; ii) energy storage and conversion technologies; iii) distributed energy resources; iv) energy policy; v) lean entrepreneurship; vi) microgrid management, control and stability.

Course Details
This is one of two complementary project-oriented graduate courses on hybrid thermal electric microgrids. Lectures and tutorials will be complemented with invited lectures from experts, site visits of energy facilities, and the direct participation of leading research labs and industry partners. Students are required to complete assignments.

Weekly course topic breakdown for Part 1:

Topic	Week(s)	Assignment
1) Introduction and concept of microgrid	1	
2) Energy storage and conversion technologies (ESCTs)	2 & 3	Report 1: Integrate multiple ESCTs scenarios in hybrid microgrids and DERs model (20%).
3) Distributed energy sources, and interfacing	4 & 5	Report 2: Map DERs in Canada; microgrid location and DERs feasibility (20%)
4) Sustainable energy policy and politics	6 & 7	Report 3: Policy brief. (10%)
SFU Reading week		
5) Lean Entrepreneurship I and II	8	Report 4: Lightweight experiment test card preparation and presentation (10%)
6) Microgrid energy management and planning	9 & 10	Report 5: Matlab script and program (20%)
7) Microgrid control and stability	11 & 12	Report 6: Analysis of a MG stability example from the references provided. (20%)

Grading

Assignments (refer to the assignment chart above for grading breakdown) 100 %

Reading list: None

Requirements

The students will be required to complete all assignments and projects on time. Specific due date for each assignment will be announced in class and/or posted on Canvas. Late submission will be subject to a penalty of 5% reduction per day. Marks will be posted on Canvas.

Course Title: MSE 453: Hybrid Thermal Electric Microgrids 1

Course Times: <TBD>
Instructor: Majid Bahrami
Delivery Method: Remote
Prerequisites: none

Calendar Description
This co-taught online course covers hybrid microgrids with strong practical training components. Topics include i) hybrid microgrid concepts, modeling and analysis; ii) energy storage and conversion technologies; iii) distributed energy resources; iv) energy policy; v) lean entrepreneurship; vi) microgrid management, control and stability.

Course Details
This is one of two complementary project-oriented courses on hybrid thermal electric microgrids. Lectures and tutorials will be complemented with invited lectures from experts, site visits of energy facilities, and the direct participation of leading research labs and industry partners. Students are required to complete assignments.

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2) Energy storage and conversion technologies (ESCTs)	2 & 3	Report 1: Integrate multiple ESCTs scenarios in hybrid microgrids and DERs model (20%).
3) Distributed energy sources, and interfacing	4 & 5	Report 2: Map DERs in Canada; microgrid location and DERs feasibility (20%)
4) Sustainable energy policy and politics	6 & 7	Report 3: Policy brief. (10%)
SFU Reading week		
5) Lean Entrepreneurship I and II	8	Report 4: Lightweight experiment test card preparation (10%)
6) Microgrid energy management and planning	9 & 10	Report 5: Matlab script and program (20%)
7) Microgrid control and stability	11 & 12	Report 6: Analysis of a MG stability example from the references provided. (20%)

Grading

Assignments 100 %

Reading list: None

Requirements

The students will be required to complete all assignments and projects on time. Specific due date for each assignment will be announced in class and/or posted on Canvas. Late submission will be subject to a penalty of 5% reduction per day. Marks will be posted on Canvas.

SFU FACULTY OF APPLIED SCIENCES

Blended Learning (Online/Hybrid)
Application for blended course delivery

Spring 2023 and Summer 2023

A. Course overview		
1.	**School / Department**	MSE
2.	**Course Number**	4XX
3.	**Course Title**	Hybrid Thermal Electric Microgrids 1
4.	**Instructor Name & Contact**	Majid Bahrami, mbahrami@sfu.ca
5.	**Course Enrolment Capacity**	40
6.	**Projected Enrolment**	20
7.	**Preferred meeting pattern** a. Tutorials or laboratories only, no lectures (No pattern restriction) b. 1 hour lecture/week (Scheduling Pattern B, blocks B1, B2 B3 [8:30], B13, B14 [1:30], B18, B19, B20 [3:30]) c. 1 hour lecture and 1 hour tutorial/week (Scheduling Pattern B, blocks B1, B2 B3 [8:30], B13, B14 [1:30], B18, B19, B20 [3:30]) d. 2 hours lecture/week (Scheduling pattern C all blocks) e. 2 hours lecture and 1-hour tutorial/week (Scheduling pattern C all blocks) f. 3 hours lecture/week (Scheduling pattern G.1/G.2 all blocks) g. Class meets for two or 3-hour lectures every week for six weeks (Scheduling pattern C or scheduling pattern G.1/G.2. Requires pairing with another course to share alternating weeks)	3 hours of scheduled online lectures The undergraduate course will be concurrent with graduate course MSE 895 G100 Special Topics III Hybrid Thermal Electric Microgrids. For Spring 2024, the MSE 895 schedule is: Lectures: Monday 10:00 am – 11:50 am PST, Thursday 10:00 am – 10:50 am PST
8.	**What is the proposed schedule for learning activities, including contact hours with the instructor?**	Course lectures (2h + 1 h each week) taught by co-instructors (or a guest presenter) with the instructor present. The students will complete six assignments with varied formats aligned with each module topic (reports, quizes, presentations, calculations, modelling).
9.	**Has the course been offered with blended delivery before?**	No. However, the online graduate course, MSE 895 Special Topics III G100 HyTEM was offered in Spring 2022 and Spring 2023.

SFU FACULTY OF APPLIED SCIENCES

Blended Learning (Online/Hybrid)
Application for blended course delivery

Spring 2023 and Summer 2023

B. Course outline

This project-oriented course covers key elements of sustainable hybrid thermal electric microgrid research and development, including:

- Concept of microgrids
- Energy storage and conversion technologies
- Distributed energy sources, and interfacing;
- Sustainable energy policy and politics
- Microgrid energy management and planning
- Microgrid control and stability
- Entrepreneurial mindsets and developing value propositions

It will be co-taught online annually, including lectures by six professors from partnering universities, and invited speakers from the (inter)national research labs and industry partners of the NSERC CREATE HyTEM program. The lectures and assignments, reports and quizzes will provide the students the opportunity to build technical, professional, and communication skills.

Hybrid Thermal Electric Microgrids 1 (Spring) and Hybrid Thermal Electric Microgrids 2 (Summer) have a distinctive modules and instructors. Hybrid Thermal Electric Microgrids 1 is not a pre-requisite for Hybrid Thermal Electric Microgrids 2.

The course is combined with annual graduate courses, MSE 895 G100 Special Topics III: Hybrid Thermal Electric Microgrids (Spring and Summer).

C. Intended learning outcomes

The course objective is to provide students with the knowledge base and skills needed to develop technical solutions and navigate the business, governmental, policymaking, and social/organizational drivers of the sustainable energy field. This course will help develop the following attributes required for graduating as an engineer:

- Knowledge Base
- Use of Engineering Tools
- Communication Skills
- Impact of Engineering on Society
- Economics and Project Management

D. Rationale for blended delivery, including benefits and implementation

The Hybrid Thermal Electric Microgrid course is co-developed and co-taught by instructors from six universities and includes invited speakers from industry and international and national research instituted. The students to benefit from course modules presented on-line by instructors with deep knowledge and expertise in a wide range of sustainable energy fields, including current research and case studies from different regions of Canada. It also enables peer-to-peer teaching and learning between undergraduate and graduate students in different disciplines through collaborative assignments.

SFU FACULTY OF APPLIED SCIENCES

Blended Learning (Online/Hybrid)
Application for blended course delivery

Spring 2023 and Summer 2023

E. Describe the active learning activities that will enhance students' experience and learning Outcome

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F. What is the proposed grading scheme?

Evaluation

Deliverables / Assignments	Weighting	Week / Date Due
Assignment 1	20	Week 1-3 / Jan. 30. Integrate multiple energy storage and conversion technologies scenarios in hybrid microgrids with distributed energy resources
Assignment 2	20	Week 4-5 / Feb. 13. Map distributed energy resources (DERs) in Canada; evaluate DERs feasibility and microgrid locations
Assignment 3	10	Week 6 / Feb. 27. Sustainable energy policy brief
Assignment 4	10	Week 9 / Mar. 13. Entrepreneurial skills: Light-weight Experiment Presentation
Assignment 5	20	Week 10-11 / Mar. 27. Microgrid energy management and planning: Matlab Script
Assignment 6	20	Week 12-13 / Apr. 13. Analysis of microgrid stability

G. Use this space for any additional information you would like to provide. *Please refer to principles below.*

Co-Instructors:
Asst. Prof. Hadis Zarrin, Dept. of Chemical Engineering, Ryerson University
Assoc. Prof. Cynthia Cruickshank, Dept. of Mechanical and Aerospace Engineering, Carleton University
Assoc. Prof. Alexandra Mallett, School of Public Policy and Administration, Carleton University
Prof. Terri Griffith, Professor, Keith Beedie Chair in Innovation and Entrepreneurship, Beedie School of Business, SFU
Prof. Bala Venkatesh, Dept. of Electrical Engineering, Ryerson University
Prof. Claudio Canizares, Dept. of Electrical and Computer Engineering, University of Waterloo

SFU FACULTY OF APPLIED SCIENCES

Blended Learning (Online/Hybrid)
Application for blended course delivery

Spring 2023 and Summer 2023

Principles for selecting blended courses

A course designated as a B will retain that designation for its lifetime.

- A blended course can be structured to perform lectures, labs, or tutorials remotely without the learning outcomes being adversely affected, or preferably with the learning outcomes enhanced.
- A blended course can be structured to promote engagement in a remote setting between the instructor/students and among students. Consideration may be given if the course may promote the engagement of international students who may not have the opportunity to engage with the SFU community outside of remote lectures.
- Students will not miss out on a hands-on learning opportunity if the course is offered remotely.
- A blended course should be well integrated between course components.
- A blended offering should not affect a student's ability to graduate, achieve a prerequisite requirement, or succeed in a future course offering.
- A blended offering should be clearly communicated to students through the course outline and in communications from the instructor.
- For the first few offerings of the blended course, feedback should be sought from students and teaching assistants on the structure of the course, learning outcomes and opportunity for engagement within the course offering.
- Students typical course planning has been taken into consideration.
- Accreditation units have been considered when designing a blended course.
- Preference may be given to courses only offered once a year or less frequently that need to be more accessible for students to progress in their degree.
- Preference may be given to course with audience spanning more than one SFU campus.

Demonstrated past success in blended offering may be considered along with the above principles and should be mentioned in the rationale.

Authorizing signatures:		
	Signature:	Date:
Instructor	Majid Bahrami	January 18, 2023
Department Director		
Faculty Dean		
Registrar		

SFU GRADUATE STUDIES

NEW GRADUATE COURSE PROPOSAL

Course Subject (eg. PSYC) MSE	**Number** (eg. 810) 754	**Units** (eg. 4) 3

Course title (max. 100 characters) Hybrid Thermal Electric Microgrids II

Short title (for enrollment/transcript - max 30 characters) Hybrid Microgrids II

Course description for SFU Calendar *(course descriptions should be brief and should never begin with phrases such as "This course will..." or "The purpose of this course is..." If the grading basis is satisfactory/unsatisfactory include this in the description. Max. 50 words)

Covers hybrid microgrids with strong practical training components. Topics include i) energy conversion and distribution systems; ii) entrepreneurial mindsets, presentation for implementation; iii) bioenergy production and natural gas network; iv) thermal energy storage materials and processes; v) thermal energy grid; vi) sensing and communication systems; and vii) energy policy. Part two of a 2-part project-oriented course.

Rationale for introduction of this course

There is a need for a holistic training that covers engineering as well as business, techno-economical, environmental, social (engagement, awareness, acceptance, participation), and policymaking aspects of emerging sustainable energy grids.

Term of initial offering (eg. Fall 2019) Summer 2025	**Course delivery** (eg 3 hrs/week for 13 weeks) 3 hrs/week for 13 weeks
Frequency of offerings/year yearly	**Estimated enrollment per offering** 20

Equivalent courses (courses that replicates the content of this course to such an extent that students should not receive credit for both courses)

MSE 454

Prerequisite and/or Corequisite

none

Criminal record check required? ☐ Yes (if yes is selected, add this as prerequisite) **Additional course fees?** ☐ Yes ☑ No

Campus where course will be taught ☐ Burnaby ☑ Surrey ☐ Vancouver ☐ Great Northern Way ☐ Off campus

Course Components* ☑ Lecture ☐ Seminar ☐ Lab ☐ Research ☐ Practicum ☐ Online ☐ Other:

Grading Basis ☑ Letter grades ☐ Satisfactory or Unsatisfactory ☐ In Progress/Complete

Repeat for credit? ☐ Yes ☑ No	**Total repeats allowed?** none	**Capstone course?** ☐ Yes ☑ No
Required course? ☐ Yes ☑ No	**Final exam required?** ☐ Yes ☑ No	**Repeat within a term?** ☐ Yes ☑ No

Combined with an undergrad course? ☑ Yes ☐ No If yes, identify which undergraduate course and what the additional course requirements are for graduate students:

MSE 454
Graduate students must do additional work including: presentations for the entrepreneurial modules and case study reports for the thermal grid module.

* See important definitions on the curriculum website.

RESOURCES

If additional resources are required to offer this course, provide information on the source(s) of those additional resources.

Faculty member(s) who will normally teach this course
Bahrami (SFU), Bahreyni (SFU), Palmer (SFU),Griffith (SFU), Canizares (Waterloo), Cruickshank (Carleton), Lau (UBC), Mallet (Carleton)
Additional faculty members, space, and/or specialized equipment required in order to offer this course
none

CONTACT PERSON

Academic Unit / Program	**Name (typically, Graduate Program Chair)**	**Email** csparrey@sfu.ca
MSE	Carolyn Sparrey	

ACADEMIC UNIT APPROVAL

☑ A course outline / syllabus is included

Non-departmentalized faculties need not sign

Department Graduate Program Committee Carolyn Sparrey	**Signature**	**Date** Dec 20, 2023
Department Chair John Zheng Shen	**Signature** John Shen Digitally signed by John Shen Date: 2023.12.20 09:35:06 -08'00'	**Date** Dec 20, 2023

FACULTY APPROVAL

The course form and outline must be sent by FGSC to the chairs of each FGSC (fgsc-list@sfu.ca) to check for an overlap in content

overlap check done? ☑ YES

This approval indicates that all the necessary course content and overlap concerns have been resolved. The Faculty/Academic Unit commits to providing the necessary resources.

Faculty Graduate Studies Committee (FGSC) Parvaneh Saeedi	**Signature**	**Date** Dec 20, 2023

A library review will be conducted. If additional funds are necessary, Graduate Studies will contact the academic unit prior to SGSC.

SENATE GRADUATE STUDIES COMMITTEE APPROVAL

Senate Graduate Studies Committee (SGSC) Mary O'Brien	**Signature**	**Date** May 16, 2024

ADMINISTRATIVE SECTION (for Graduate Studies office only)

Course Attribute: _____
Course Attribute Value: _____
Instruction Mode: _____
Attendance Type: _____

If different from regular units:
Academic Progress Units: _____
Financial Aid Progress Units: _____

Course Title: Hybrid Thermal Electric Microgrids 2

Course Times: <TBD>
Instructor: Majid Bahrami
Delivery Method: Remote
Prerequisites: none

Calendar Description
This course covers hybrid microgrids with strong practical training components. Topics include i) energy conversion and distribution systems; ii) entrepreneurial mindsets, presentation for implementation; iii) bioenergy production and natural gas network; iv) thermal energy storage materials and processes; v) thermal energy grid; vi) sensing and communication systems; and vii) energy policy.

Course Details
This is one of two complementary project-oriented graduate courses on hybrid thermal electric microgrids. Lectures and tutorials will be complemented with invited lectures from experts, site visits of energy facilities, and the direct participation of leading research labs and industry partners. Students are required to complete assignments.

Weekly course topic breakdown:

Topic	Week(s)	Assignment
1) Energy conversion and distribution systems in microgrids	1 & 2	Report 1: Energy conversion and distribution systems in microgrids (16%)
2) Entrepreneurial mindsets and presentation for implementation	3	Report 2: Innovation presentation ("live pitch") (10%)
3) Bioenergy production and natural gas network	4 & 5	Report 3: Assignment on estimation of RNG production and cost analysis (16%)
4) Thermal energy storage materials and processes	6 & 7	Report 4: Assignment on calculation of energy density (16%)
5) Thermal energy grid	8 & 9	Report 5: Prepare a case study of the assigned district energy network project. (16%)
6) Sensing and communication systems	10 & 11	Report 6: Monitoring of microgrids, integration, and resiliency in the microgrid model (16%)
7) Sustainable energy policy and politics	12	Report 7: Policy brief. (10%)

Grading

Assignments (refer to the assignment chart above for grading breakdown) 100 %

Reading list: None

Requirements

The students will be required to complete all assignments and projects on time. Specific due date for each assignment will be announced in class and/or posted on Canvas. Late submission will be subject to a penalty of 5% reduction per day. Marks will be posted on Canvas.

Course Title: MSE 454: Hybrid Thermal Electric Microgrids 2

Course Times: <TBD>
Instructor: Majid Bahrami
Delivery Method: Remote
Prerequisites: none

Calendar Description
This co-taught online course covers hybrid microgrids with strong practical training components. Topics include i) energy conversion and distribution systems; ii) entrepreneurial mindsets, presentation for implementation; iii) bioenergy production and natural gas network; iv) thermal energy storage materials and processes; v) thermal energy grid; vi) sensing and communication systems; and vii) energy policy.

Course Details
This is one of two complementary project-oriented courses on hybrid thermal electric microgrids. Lectures and tutorials will be complemented with invited lectures from experts, site visits of energy facilities, and the direct participation of leading research labs and industry partners. Students are required to complete assignments.

Weekly course topic breakdown:

Topic	Week(s)	Assignment
1) Energy conversion and distribution systems in microgrids	1 & 2	Report 1: Energy conversion and distribution systems in microgrids (16%)
2) Entrepreneurial mindsets and presentation for implementation	3	Report 2: Innovation pitch (10%)
3) Bioenergy production and natural gas network	4 & 5	Report 3: Assignment on estimation of RNG production and cost analysis (16%)
4) Thermal energy storage materials and processes	6 & 7	Report 4: Assignment on calculation of energy density (16%)
5) Thermal energy grid	8 & 9	Report 5: Model a district energy network. (16%)
6) Sensing and communication systems	10 & 11	Report 6: Monitoring of microgrids, integration, and resiliency in the microgrid model (16%)
7) Sustainable energy policy and politics	12	Report 7: Policy brief. (10%)

Grading

Assignments 100 %

Reading list: None

Requirements

The students will be required to complete all assignments and projects on time. Specific due date for each assignment will be announced in class and/or posted on Canvas. Late submission will be subject to a penalty of 5% reduction per day. Marks will be posted on Canvas.

SFU FACULTY OF APPLIED SCIENCES

Blended Learning (Online/Hybrid)
Application for blended course delivery

Spring 2023 and Summer 2023

A. Course overview		
1.	**School / Department**	MSE
2.	**Course Number**	4XX
3.	**Course Title**	Hybrid Thermal Electric Microgrids 2
4.	**Instructor Name & Contact**	Majid Bahrami, mbahrami@sfu.ca
5.	**Course Enrolment Capacity**	40
6.	**Projected Enrolment**	20
7.	**Preferred meeting pattern** a. Tutorials or laboratories only, no lectures (No pattern restriction) b. 1 hour lecture/week (Scheduling Pattern B, blocks B1, B2 B3 [8:30], B13, B14 [1:30], B18, B19, B20 [3:30]) c. 1 hour lecture and 1 hour tutorial/week (Scheduling Pattern B, blocks B1, B2 B3 [8:30], B13, B14 [1:30], B18, B19, B20 [3:30]) d. 2 hours lecture/week (Scheduling pattern C all blocks) e. 2 hours lecture and 1-hour tutorial/week (Scheduling pattern C all blocks) f. 3 hours lecture/week (Scheduling pattern G.1/G.2 all blocks) g. Class meets for two or 3-hour lectures every week for six weeks (Scheduling pattern C or scheduling pattern G.1/G.2. Requires pairing with another course to share alternating weeks)	3 hours of scheduled online lectures The undergraduate course will be concurrent with graduate course MSE 895 G100 Special Topics III Hybrid Thermal Electric Microgrids. For Spring 2024, the MSE 895 schedule is: Lectures: Monday 10:00 am – 11:50 am PST, Thursday 10:00 am – 10:50 am PST
8.	**What is the proposed schedule for learning activities, including contact hours with the instructor?**	Course lectures (2h + 1 h each week) taught by co-instructors (or a guest presenter) with the instructor present. The students will complete six assignments with varied formats aligned with each module topic (reports, quizzes, presentations, calculations, modelling).
9.	**Has the course been offered with blended delivery before?**	No. However, the online graduate course, MSE 895 Special Topics III HyTEM Summer Term course was first offered 2022 and will be offered in 2023.

SFU FACULTY OF APPLIED SCIENCES

Blended Learning (Online/Hybrid)
Application for blended course delivery

Spring 2023 and Summer 2023

B. Course outline

This project-oriented course covers key elements of sustainable hybrid thermal electric microgrid research and development, including:

- Energy conversion and distribution systems in microgrids
- Entrepreneurial mindsets and developing value propositions
- Bioenergy production and natural gas network
- Thermal energy storage materials and processes
- Thermal energy grid
- Sensing and communication systems
- Sustainable energy policy and politics

It will be co-taught online annually, including lectures by six professors from partnering universities, and invited speakers from the (inter)national research labs and industry partners of the NSERC CREATE HyTEM program. The lectures and assignments, reports and quizzes will provide the students the opportunity to build technical, professional, and communication skills.

Hybrid Thermal Electric Microgrids 1 (Spring) and Hybrid Thermal Electric Microgrids 2 (Summer) have a distinctive modules and instructors. Hybrid Thermal Electric Microgrids 1 is not a pre-requisite for Hybrid Thermal Electric Microgrids 2.

The course is combined with annual graduate courses, MSE 895 G100 Special Topics III: Hybrid Thermal Electric Microgrids (Spring and Summer).

C. Intended learning outcomes

The course objective is to provide students with the knowledge base and skills needed to develop technical solutions and navigate the business, governmental, policymaking, and social/organizational drivers of the sustainable energy field. This course will help develop the following attributes required for graduating as an engineer:

- Knowledge Base
- Use of Engineering Tools
- Communication Skills
- Impact of Engineering on Society
- Economics and Project Management

D. Rationale for blended delivery, including benefits and implementation

The Hybrid Thermal Electric Microgrid course is co-developed and co-taught by instructors from six universities and includes invited speakers from industry and international and national research instituted. The students to benefit from course modules presented on-line by instructors with deep knowledge and expertise in a wide range of sustainable energy fields, including current research and case studies from different regions of Canada. It also enables peer-to-peer teaching and learning between undergraduate and graduate students in different disciplines through collaborative assignments.

SFU FACULTY OF APPLIED SCIENCES

Blended Learning (Online/Hybrid)
Application for blended course delivery

Spring 2023 and Summer 2023

E. Describe the active learning activities that will enhance students' experience and learning Outcome

F. What is the proposed grading scheme?

Evaluation

Deliverables / Assignments	Weighting	Week / Date Due
Assignment 1	16	Week 1-2 / May 25. Energy conversion and distribution systems in microgrids
Assignment 2	10	Week 3 / June 1. Entrepreneurial skills, developing value propositions. Light-weight Experiment Presentation
Assignment 3	16	Week 4-5 / June 15. Assignment on estimation of RNG production and cost analysis
Assignment 4	16	Week 6-7 / June 29. Calculation of thermal energy density
Assignment 5	16	Week 8-9 / July 17. Model a district energy network
Assignment 6	16	Week 10-11 / July 31 Monitoring of microgrids, integration, and resiliency in the microgrid model
Assignment 7	10	Week 12-13 / Aug. 11. Sustainable energy policy brief.

G. Use this space for any additional information you would like to provide. *Please refer to principles below.*

Co-instructors:
Prof. Patrick Palmer, School of Mechatronic Systems Engineering, SFU
Prof. Terri Griffith, Keith Beedie Chair in Innovation and Entrepreneurship, Beedie School of Business, SFU
Assoc. Prof. Anthony Lau, Dept. of Chemical and Biological Engineering, University of British Colombia
Prof. F. Handan Tezel, Dept. of Chemical and Biological Engineering, University of Ottawa
Prof. Behraad Bahreyni, School of Mechatronic Systems Engineering, SFU
Assoc. Prof. Alexandra Mallett, School of Public Policy and Administration, Carleton University

SFU FACULTY OF APPLIED SCIENCES

Blended Learning (Online/Hybrid)
Application for blended course delivery

Spring 2023 and Summer 2023

Principles for selecting blended courses

A course designated as a B will retain that designation for its lifetime.

- A blended course can be structured to perform lectures, labs, or tutorials remotely without the learning outcomes being adversely affected, or preferably with the learning outcomes enhanced.
- A blended course can be structured to promote engagement in a remote setting between the instructor/students and among students. Consideration may be given if the course may promote the engagement of international students who may not have the opportunity to engage with the SFU community outside of remote lectures.
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- A blended course should be well integrated between course components.
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- A blended offering should be clearly communicated to students through the course outline and in communications from the instructor.
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Authorizing signatures:		
	Signature:	Date:
Instructor	Majid Bahrami	January 18, 2023
Department Director		
Faculty Dean		
Registrar		