Faculty of Engineering and Applied Science

Mechanical & Materials Engineering

MECH 465 – Computer Aided Design

Course Outline – Fall 2015

Instructor Information

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Teaching Assistant Information

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Calendar description

Concept of computational design including the choice of the objective function, equality and inequality constraints, and analysis methods; one-dimensional search methods, sensitivity analysis, and the steepest descent method. The principles of the finite element method and its application to stress analysis of mechanical components. (0/0/0/11/31)

NOTE: Enrolment is limited.

PREREQUISITE: Permission of the instructor

Indicators and Outcomes

Graduate attribute indicators

MECH 465 develops the Canadian Engineering Accreditation Board Graduate Attributes through twenty-eight indicators, with their corresponding **Error! Reference source not found.**.

Graduate Attribute Indicators – Faculty of Applied Science (APSC)

APSC-4-CO-3: Demonstrates conciseness, precision, and clarity of language in technical writing. [Intermediate] - [CLO 4]

APSC-4-CO-4: Demonstrates confidence in formal and informal oral communications. [Intermediate] - [CLO 4]

APSC-4-CO-6: Uses graphics to explain, interpret, and assess information. [Advanced] - [CLO 2, 4]

APSC-4-DE-1: Follows appropriate iterative design process involving knowledge, creativity, justifiable decision making, analysis, and tools. [Advanced] - [CLO 1, 3, 5]

APSC-4-DE-2: Fully identifies problem and constraints including health and safety risks, applicable standards, economic, environmental, cultural, societal and ethical considerations. [Intermediate] - [CLO 1, 2]

APSC-4-DE-3: Develops detailed specifications and metrics incorporating performance requirements, constraints, assumptions, and other stated and unstated factors from all stakeholders relevant to the specific application. [Intermediate] - [CLO 3]

APSC-4-DE-4: Applies creative approaches to identify and develop alternative concepts and procedures. [Advanced] - [CLO 1, 2, 3]

APSC-4-DE-5: Uses appropriate calculations, models, simulations, analysis, and/or prototypes at various points in design with interaction and complexity appropriate to design stage. [Advanced] - [CLO 1, 2, 3]

APSC-4-DE-6: Quantifies performance/yield/efficiency/output at appropriate stages through process to support design iteration and optimization. [Intermediate] - [CLO 3]

APSC-4-ET-1: Evaluates techniques, resources, and tools to identify their limitations with respect to needs. [Introductory] - [CLO 1, 2, 3]

APSC-4-ET-2: Applies appropriate techniques, tools, and processes to accomplish a task. [Advanced] - [CLO 2, 4]

APSC-4-ET-3: Evaluates appropriateness of results from several engineering techniques and tools. [Advanced] - [CLO 2]

APSC-4-LL-1: Defines and articulates the needed information resulting from an assigned project using self-determined structures and processes. [Advanced] - [CLO 2, 3]

APSC-4-LL-4: Organises and manages different types of disciplinary information using self-determined structures, processes, and tools. (e.g. dropbox, zotero, Google Docs, etc.). [Advanced] - [CLO 2, 5]

APSC-4-LL-5: Assesses project progress and outcome using technical, professional, and other relevant measurements. [Introductory] - [CLO 2, 4]

APSC-4-PA-7: Assesses the reasonableness and effectiveness of assumptions, methods and quality of results against appropriate standards, and draws conclusions and recommend further investigation. [Advanced] - [CLO 1, 3, 4]

APSC-4-PR-2: Demonstrates professional bearing. [Introductory] - [CLO 4]

APSC-4-TW-1: Shows respect for diversity in individuals and roles in a team. [Intermediate] - [CLO 4, 5]

APSC-4-TW-3: Elicits and applies positive and effective feedback from mentors and peers in technical, communications, and/or team issues. [Introductory] - [CLO 4]

APSC-4-TW-4: Demonstrates capacity for initiative and leadership in team operations while respecting others' roles. [Advanced] - [CLO 4, 5]

Graduate Attribute Indicators – Mechanical & Materials Engineering (MECH)

MECH-4-XX-##1: Review solid mechanics and extend the concepts to applications in numerical problems [Introductory] - [CLO 1]

MECH-4-XX-##2: Explain finite element method procedure for linear static structural problems. [Intermediate] - [CLO 1]

MECH-4-XX-##3: Formulate element stiffness matrices for 1D Bar and 2D Beam Elements [Intermediate] - [CLO 1]

MECH-4-XX-##4: Assemble multiple element stiffness matrices using 1D Bar or 2D Beam Elements for simplified structures [Advanced] - [CLO 1]

MECH-4-XX-##5: Determine displacement, strain, and stress fields for 1D Bar and 2D Beam Element problems by hand [Advanced] - [CLO 1]

MECH-4-XX-##6: Determine displacement, strain, and stress fields for 3D Solid Element problems computationally [Intermediate] - [CLO 1, 2]

MECH-4-XX-##7: Formulate a mathematical optimization statement for a given problem or task [Introductory] - [CLO 3]

MECH-4-XX-##8: Determine the optimal solution for a particular structural problem using the steepest descent optimization method [Advanced] - [CLO 3]

Course Learning Outcomes (CLOs)

By the end of this course, learners should be able to:

CLO 1: Learn the fundamental principles and practical techniques of the Finite Element Method (FEM)

CLO 2: Develop beginner to intermediate level of practical user experience with industry standard Finite Element Analysis (FEA) software packages such as ANSYS

CLO 3: Acquire design optimization techniques and apply it to structural-related projects

CLO 4: Effectively communicate and present design ideas

CLO 5: Develop practical experience in project and product design management

Prerequisite knowledge

This course is designed for engineering students in mechanical engineering or related areas. It is essential for the students to have a strong background in statics and solid mechanics. It is also necessary to have an initial or intermediate background in materials science. A background in the finite element method (FEM), computer aided engineering (CAE) analysis, or optimization is not required.

Course length and pace

This course represents a study period of one semester, and is divided into 12 weeks of labs and lectures. Learners can expect to invest on average 7-9 hours per week on average in this course. The workload for the group project is heavy, and parametric modeling of the finite element model in particular is time consuming. At the end of this document is a Timetable and more detail is found on the class website.

Student attendance at all lectures and lab sessions is mandatory, with exceptions only given in the case of medical or family emergencies. In the case of such emergencies, students must contact the professor and/or lead TA as soon as they are capable, in order to arrange alternative accommodations.

It is strongly recommended that students begin work on the final project as early as possible, in order to encourage a more consistent work distribution throughout the semester. Project progress will be addressed regularly in labs to ensure that students are on schedule.

Academic integrity

Engineers have a duty to:

- Act at all times with devotion to the high ideals of personal honour and professional integrity
- Give proper credit for engineering work

-Professional Engineers Ontario Code of Ethics, Section 77 of the O. Reg. 941
http://peo.on.ca/index.php?ci_id=1815&la_id=1

The quote above describes the standard of behaviour expected of professional engineers. As engineering students, you have made a decision to join us in the profession of engineering, a long-respected profession with high standards of behaviour.

As future engineers, we expect you to behave with integrity at all times. Our policies do not prohibit you from collaborating, even closely, with fellow learners in any class. Indeed, we strongly encourage collaboration and teamwork, when conducted responsibly. We have however, set firm guidelines on the quality of submitted work and have taken a strong stand against plagiarism and other forms of academic dishonesty. Briefly stated, we expect that submitted work bears the name of all those contributing to it, and that you do not allow others to copy your work.

Should a student's submitted work be suspected of containing evidence of academic dishonesty, action shall be taken, as required by the Faculty of Applied Science policy on academic integrity: *http://engineering.queensu.ca/policy/Honesty.html*

Additional information on the University's policies concerning academic dishonesty can be found on the Queen's website. **All learners are expected to familiarize themselves with these policies** and to conduct themselves accordingly.

- *Senate Academic Integrity Policy Statement*
- *Procedures for dealing with departures from academic integrity in the Faculty of Engineering and Applied Science*
- *Queen's University Code of Conduct*

Expectations for interaction

There will be opportunities to interact with your instructor, TA(s) and fellow classmates throughout this course. As highlighted above, students are expected to behave with integrity at all times. If a student has a confidential matter that he/she would like to discuss with an instructor, he/she should contact the instructor via the email addresses and/or telephone numbers at the top of this document. The Instructor will be also available for discussion during the office hours, which will be announced in class.

TAs will be available to answer questions regarding course material during labs, and during the TA office hours, which will be given in class, and posted on the course website. Email inquiries regarding special accommodations and/or course content will be addressed as soon as possible, and can be expected within 2 business days at the most.

Course-specific policies

In keeping with the Faculty of Engineering and Applied Science *Faculty Regulation 5b*, "A student who claims illness or compassionate grounds as a reason for missing any required component of the course other than the final exam is responsible for making alternative arrangements with the instructors concerned." Note that unacceptable reasons include: malfunctioning computer, travel plans to go home for holidays, generally behind on schoolwork, etc. The instructor will request some substantiating documentation. If alternate arrangements are not agreed upon, then the normal late penalty will apply as described in the assignment.

Attendance in all MECH 465 lectures and all labs is ***mandatory***, and if any extenuating circumstances arise, it is imperative that the affected student contact the instructor as soon as possible. The instructor reserves the right to determine the acceptability of any given reasons for missing lectures. Official written documentation will be required in ALL circumstances.

Lecture notes from any missed lectures will be available for hand copying during the lead TA's assigned office hours, which will be posted online, and in the introductory lectures at the beginning of the year.

Individual Needs and Support

Learners with diverse learning styles and needs are welcome at Queen's. In particular, if you have a disability or health consideration that may require accommodations, please feel free to approach the instructor and/or Accessibility Services ***as soon as possible***. While every effort will be made to accommodate the needs of all students, the instructor cannot guarantee availability of such accommodations when given insufficient notice. As such, ***it is the responsibility of the* student** to inform the instructor at the beginning of the term of their needs. The Accessibility Services staff is available by appointment to develop individualized accommodation plans, provide referrals and assist with advocacy. The sooner the student inform the instructor of his/her needs, the better the student can be assisted in achieving the learning goals at Queen's. For further information, visit the *Student Wellness Services* website. The class website is powered by the Brightspace by D2L Learning Environment that *complies with common accessibility standards* and every effort has been made to provide course materials that are accessible.

Academic and Student Support

Queen's has a robust set of resources available to you including, but not limited to the *Library*, *Student Academic Success Services (Learning Strategies and Writing Centre)*, and *Career Services*. Students are encouraged to visit the Faculty of Engineering and Applied Science *Current Students* web portal for information about various other policies such as academic advisors, registration, student exchanges, awards and scholarships, etc.

Technical Skills and Support

There are no prerequisite specialized computer-related technical skills for this course, but students will be expected to work extensively with the finite element analysis (FEA) program ANSYS. Instruction will be given in labs, and teaching assistants will be made available for any technical questions. If students have any issues regarding the software requirements associated with the course, they are encouraged to contact the lead TA as soon as possible. For computer-specific technical assistance, students are advised to contact *Technical Support*.

Evaluation

Activity	Due Date	Weight	Alignment with UDLEs[1]	Alignment with CLOs
Homework Assignments (3)	Fridays of weeks 2, 4, and 6, **At 4:00 p.m. EST**	3 @ 5% each = **15% total**	UDLEs 1,2,3,4,5,6	CLOs 1,4,5
Lab Assignments (7)	Tuesdays of weeks 3, 4, 5, 6, 8, 9, and 10, **At 6:30 p.m. EST**	7 @ 0.714% each = **5% total**	UDLEs 1,2,3,4,5,6	CLOs 1,2,3,4,5
Team Project (4 Tasks)	Task 1 – Tuesday of Week 08, Task 2 – Tuesday of Week 10, Task 3 – **Monday** of Week 12, Task 4 – Tuesday of Week 13, ***At 8:00 p.m. EST***	Task 1 @ 09% + Task 2 @ 09% + Task 3 @ 09% + Task 4 @ 18% = **45% Total**	UDLEs 1,2,3,4,5,6	CLOs 1,2,3,4,5
Test (Proctored)	During a lecture period, **Exact time TBA**	**25%**	UDLEs 1,2,3,4,5,6	CLOs 1,3,4,5
Attendance & Active Participation	N/A	**10%**	UDLEs 1,2,3,4,5	CLOs 1,2,3,4,5
	Total	**100%**		

Homework Assignments

The homework assignments are distributed on D2L and they can involve questions that are a mixture of calculations, and short answer questions based on lecture material that was recently covered. Students have a week to complete this assignment and the submission format is a hard copy submitted into the McLaughlin 3rd floor dropbox.

Lab Assignments

The lab assignments are initiated at the end of each tutorial section that involves learning the use of ANSYS for various tasks. Students are expected to write a 3-page report with their project team members and must submit it electronically on the corresponding D2L dropbox on the class website. Students must submit the lab assignment a week after the lab has been completed, and at the latest.

Team Project

More information about the Project can be found in Project Instructions which is posted on D2L.

Test

The date, time, and location of the test will be announced in lecture as well as posted on D2L. The test is closed book; however, a formula sheet will be provided if needed.

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[1] As per "Guidelines for University Undergraduate Degree Level Expectations," December 16, 2005. *http://www.queensu.ca/ctl/what-we-do/learning-outcomes-coursecurriculum-design-and-review/queens-new-quality-assurance*

Attendance & Active Participation

Students must attend all lectures and all labs throughout the term. Lecture and lab attendance will be taken by the instructor, and the lead TA, respectively. Students must inform the instructor BEFORE a class in case of a medical or family emergency which prevents them from attending, so that alternative accommodations can be arranged and that attendance may be excused if the reason is determined to be valid by the instructor. Otherwise, there will be no exceptions to this rule. The 10% attendance and participation grade will be based on these attendance records.

Course materials

Required textbook

- Robert D. Cook, *Finite Element Modeling for Stress Analysis*, John Wiley & Sons

If you have not already purchased the textbook and additional chapters on Business and Entrepreneurship required for this course, go to *www.campusbookstore.com* and follow the "Textbook Search Engine" link. Note that a copy of the textbook is available for review during TA office hours.

Required calculator

- A Casio 991 OR a comparable, gold sticker-approved calculator. **ONLY** this type of non-programmable, non-communicating calculator will be allowed during tests and exams.

Lecture notes

All lecture notes will be available with blanks for download online, from the D2L Brightspace website at *https://courses.engineering.queensu.ca/* and students are expected to fill in the blanks, based on the instructor's slides, which will be presented in lecture. For students that miss lectures, a copy of the instructor's notes will be available for hand copying during the lead TA's office hours; only hand copying is allowed, and no photocopying or taking a photograph is allowed.

Optional textbook

Finite Element Method

- Robert D. Cook et al., *Concepts and Applications of Finite Element Analysis*, 3rd edition, John Wiley & Sons

Design Optimization

- Jasbir S. Arora, *Introduction to Optimum Design*, 2nd edition, McGraw-Hill
- Panos Y. Papalambros and Douglass J. Wilde, *Principles of Optimal Design*, 2nd edition, Cambridge University Press

Other material

All other course material is accessible via the course page on the D2L Brightspace website.

Timetable

Week	Learning Outcomes (with alignment to CLOs shown in square brackets)	Deliverables (with alignment to CLOs shown in square brackets)
1	**Introduction to FEA & review of solid mechanics** After completing this week, learners will be able to: • Explain the fundamentals of solid mechanics, as outlined in MECH 321 • Explain strain-displacement & stress-strain relationships in the context of the finite element method (FEM) • Determine the general governing equations & boundary conditions when using FEM • Understand an overview of the procedure to formulate and solve problems using FEM and finite element analysis (FEA)	
2	**Introduction to 1-D Bar Elements & ANSYS** After completing this week, learners will be able to: • Explain the shape function matrix, strain, and stress for a 1-D Bar Element • Apply the necessary procedure to solve a simple finite element analysis problem by hand using 1-D bar elements to formulate the problem • Discuss the validity, accuracy and applicability of using 1-D bar elements to represent physical systems • Use basic functions within the ANSYS GUI interface to solve simple structural problems	**Assignment #1** [CLO 1]
3	**Element Dimension, Beam Theory & ANSYS Overview** After completing this week, learners will be able to: • Explain the shape function matrix, strain, and stress for a *n*-D Elements • Apply the necessary procedure to solve a simple finite element analysis problem by hand using 2-D beam elements to formulate the problem • Understand how to structure FEA problems in ANSYS	**Lab #1** [CLO 2, 4]

Week	Learning Outcomes (with alignment to CLOs shown in square brackets)	Deliverables (with alignment to CLOs shown in square brackets)
4	**Beam Theory (continued), von-Mises Stress & ANSYS Command/Batch Mode** After completing this week, learners will be able to: • Apply the necessary procedure to solve a simple finite element analysis problem by hand using 2-D beam elements to formulate the problem • Explain the concepts behind and physical implications of the engineering definitions of mechanical stress, strength, and static failure, as outlined in MECH 321 • Explain von-Mises Stress in the context of the finite element method (FEM) • Use command and batch mode in ANSYS to solve simple structural problems	**Assignment #2** [CLO 1, 4] **Lab #2** [CLO 2, 4]
5	**Shape Function, & Bottom-Up Modeling** After completing this week, learners will be able to: • Explain how to use shape functions to interpolate the displacement field within a plane rectangular bilinear element • Demonstrate the bottom-up modeling approach to constructing intermediate to complex geometries • Understand the advantages and disadvantages to using bottom-up modeling in ANSYS	**Lab #3** [CLO 2, 4, 5]
6	**Gauss Quadrature, Meshing & Coordinate Systems in ANSYS** After completing this week, learners will be able to: • Explain gauss quadrature integration in the context of determining the stress field within an element • Understand the advantages and disadvantages to hexahedral vs. tetrahedral elements, and mapped vs free meshing • Use various types of global and local coordinate systems when modeling in ANSYS	**Assignment #3** [CLO 1, 4, 5] **Lab #4** [CLO 1, 2, 4, 5]
7	**Introduction to Design Optimization & ANSYS Modeling** After completing this week, learners will be able to: • Explain a design optimization statement and the process to formulate one from a given problem • Understand design optimization from a graphical interpretation • Use various types of global and local coordinate systems when modeling in ANSYS	

Week	Learning Outcomes (with alignment to CLOs shown in square brackets)	Deliverables (with alignment to CLOs shown in square brackets)
8	**Gradient, Steepest Descent Method, & Parametric Modeling** After completing this week, learners will be able to: • Explain properties, characteristics of both gradient based methods in context of design optimization • Set up a parametric model in ANSYS to enable change the geometry of a model by varying certain parameters	**Lab #5** [CLO 2, 4, 5] **Project Task #1** [CLO 1, 2, 4, 5]
9	**Finite Difference Method & Sensitivity Analysis** After completing this week, learners will be able to: • Explain the use of sensitivity analysis in the context of optimization convergence behavior and computational expense • Learn how to set up a first order optimization in ANSYS **Test** The following topics has the potential to appear on the test: • Force Equilibrium, Strain-Displacement & Stress-Strain relationships for 3D • Plane Strain & Plane Stress assumptions • FEM Procedure along with its corresponding advantages and disadvantages • Determine the displacement, stress, and strain fields for 1D bar element problems using the procedure taught in lecture • Determine the displacement, stress, and strain fields for 2D beam element problems using the procedure taught in lecture • Von-Mises Stress and Stress Intensity • Yielding Criteria in 2D and 3D Stress state • Shape function matrix of 2D bilinear elements • Gauss Quadrature Integration • Mathematical optimization statement formulation, and identifying feasible design vs infeasible design • Graphical interpretation of design optimization • Iterative optimization procedure	**Lab #6** [CLO 1, 2, 4, 5] **Test #1** [CLO 1, 2, 3, 4, 5]
10	**Mesh Convergence, Modelling Errors & Other Optimization Methods** After completing this week, learners will be able to: • Understand the importance of mesh convergence and inherent modeling errors associated with numerical methods • Learn about other optimization methods in a holistic and high-level overview perspective	**Lab #7** [CLO 1, 2, 3, 4, 5] **Project Task #2** [CLO 1, 2, 4, 5]

Week	Learning Outcomes (with alignment to CLOs shown in square brackets)	Deliverables (with alignment to CLOs shown in square brackets)
11	**Multi-Disciplinary Optimization (MDO), Multi-Objective Optimization (MOO) and Design under uncertainty** After completing this week, learners will be able to: • Gain introductory-level knowledge of MDO, MOO and design under uncertainty concepts	
12	**Project Task 3 – Group Presentations** • Demonstrate their understanding of static structural finite element analysis, design optimization, and proficiency using ANSYS • Give a 7-minute presentation that clearly and concisely provide an overview or their project in a professional setting	**Project Task #3** [CLO 1, 2, 3, 4, 5]
13	**Project Task 3 – Group Presentations** • Demonstrate their understanding of static structural finite element analysis, design optimization, and proficiency using ANSYS • Write a final report, in ASME conference paper format that coherently integrates all aspects of the project into five-pages	**Project Task #4** [CLO 1, 2, 3, 4, 5]

General feedback

Your input is essential for maintaining and improving the quality of this course material for future offerings, e.g., course content, typos, assignments, readings, course design. Email your comments to the instructor. Your input will also be solicited in course evaluation surveys.

Important information

Your instructor is your first point of contact. Their contact information can be found at the top of this document. If you have questions about this course during the semester, contact your instructor. Please use email as the primary means of content, **and be sure to allow 2 business days for a response.**