Faculty of Engineering and Applied Science

Mechanical & Materials Engineering

MECH 323 – Machine Design

Course Outline – Winter 2016

Instructor Information

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Teaching Assistant Information

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All necessary Teaching Assistant (TA) contact information can be found on the class website.

Calendar description

This course emphasizes the application of theoretical and engineering background taught in other courses, but also relies heavily on empirical approaches and simplifications of theory. Core material includes static and fatigue failure theories and the design/specification of selected machine elements. The course is centered on a major design project which is undertaken in groups.

Prerequisites: APSC 200 or MECH 212, APSC 221 or MTHE 334, MECH 321

Indicators and Outcomes

Graduate attribute indicators

MECH 323 develops the Canadian Engineering Accreditation Board Graduate Attributes through twenty-seven indicators, with their corresponding Course Learning Outcomes (CLOs).

Graduate Attribute Indicators – Faculty of Applied Science (APSC)

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

APSC-3-CO-5: Demonstrates effective informal oral communication; effectively listens and responds to questions. [Introductory] - [CLO 4]

APSC-3-CO-6: Constructs accurate and complete technical graphics. [Advanced] - [CLO 1, 2, 4]

APSC-3-DE-1: Applies technical knowledge, models/simulations, and/or appropriate computer aided design tools with iteration to analyze and construct potential design solutions to complex open-ended problems. [Advanced] - [CLO 1, 3, 5]

APSC-3-DE-2: Defines a problem in detail, including unstated customer/user/stakeholder needs, aesthetics, usability, user interface or other elements that impact user/operator experience. [Introductory] - [CLO 2]

"APSC-3-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. [Advanced] - [CLO 2]"

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

APSC-3-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 3, 5]

APSC-3-DE-6: Quantifies performance/yield/efficiency/output at appropriate stages through process to support design iteration and optimization. [Advanced] - [CLO 1, 3]

APSC-3-ET-1: Selects and applies, with some guidance, appropriate techniques, tools, and processes to accomplish a task. [Introductory] - [CLO 3]

APSC-3-ET-3: Describes limitations/uncertainties of engineering tools used and validates credibility of model with first principle analysis or empirical measurement. [Advanced] - [CLO 1, 5]

APSC-3-ET-4: Selects and applies appropriate techniques such as modelling, simulation, and/or fabrication process to validate design. [Advanced] - [CLO 3]

APSC-3-LL-5: Assesses project progress and outcome using technical, professional, and other relevant measurements. [Introductory] - [CLO 2, 4]

APSC-3-PR-1: Identifies and uses constraints in decision making process including health and safety risks, applicable standards and codes of practice, economic, legal, environmental, cultural and societal considerations. [Introductory] - [CLO 2, 5]

APSC-3-PR-2: Demonstrates professional bearing. [Introductory] - [CLO 2]

APSC-3-TW-1: Shows respect for diversity in individuals and roles in a team. [Introductory] - [CLO 2]

APSC-3-TW-3: Elicits and applies positive and effective feedback from mentors and peers in technical, communications, and/or team issues. [Introductory] - [CLO 2]

APSC-3-TW-4: Demonstrates initiative and leadership in team operations while respecting others' roles. [Introductory] - [CLO 2]

Graduate Attribute Indicators – Mechanical & Materials Engineering (MECH)

MECH-3-KB-240: Explain failure theories due to static loading. [Introductory] - [CLO 3, 5]

MECH-3-KB-241: Explain failure theories due to dynamic loading (fatigue theories). [Advanced] - [CLO 3, 5]

MECH-3-KB-242: Explain mathematical relationships among gear ratio, number of teeth, torque ratio, and angular velocity ratio for mating gears. [Intermediate] - [CLO 3]

MECH-3-KB-243: Determine optimum gear ratio, calculate the number of gear teeth, and choose proper pressure angle and module which does not generate gear interference. [Intermediate] - [CLO 3]

MECH-3-KB-244: Determine all forces acting on 1-stage and 2-stage gears, and draw a complete free body diagram that show all external forces and torques in each case. [Intermediate] - [CLO 3, 4]

MECH-3-KB-245: Calculate safety factor of a gear with respect to fatigue failure due to bending and contact loading, according to the AGMA (American Gear Manufacturers Associations) standards. [Advanced] - [CLO 1]

MECH-3-KB-246: Determine stress concentration factors for various shaft geometries under static and dynamic loading. [Advanced] - [CLO 3]

MECH-3-KB-247: Calculate safety factor of a shaft with respect to fatigue failure due to bending moment and torsion. [Introductory] - [CLO 3, 5]

MECH-3-KB-248: Explain various types of bearings and calculate bearing rating life under combined radial and thrust loading. [Advanced] - [CLO 3]

Course Learning Outcomes (CLOs)

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

CLO 1: Learn and gain practical experience of the mechanical design process to solve real-world problems, while adhering to mandated standards

CLO 2: Develop practical experience in project and product life-cycle management

CLO 3: Develop an understanding of machine design theories and their applications

CLO 4: Effectively communicate and present design ideas

CLO 5: Understanding the risks involved in design failures and implementing proper risk mitigation techniques

Prerequisite knowledge

This course is designed for engineering students, with a preliminary background in statics, solid mechanics, and materials science. It is essential for the students to have a strong background in statics and solid mechanics.

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. At the end of this document is a Timetable and more detail is found on the class website.

Student attendance at all lectures and all lab sessions is mandatory, with exceptions only given in the case of medical and 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.

Attendance in all MECH 323 lectures and all labs is ***mandatory***, and if any extenuating circumstances arise, it is imperative that the affected student contact the instructor and/or lead TA 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 CAD modelling program NX. 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 (at 5:00 p.m. EST, unless otherwise specified)	Weight	Alignment with UDLEs[1]	Alignment with CLOs
Design Project (Phase 1)	Saturday of week 6	7.2%	ALL UDLEs	ALL CLOs
Design Project (Phase 2)	Wednesday of week 8	12.0%	ALL UDLEs	ALL CLOs
Design Project (Phase 3)	Saturday of week 10	14.4%	ALL UDLEs	ALL CLOs
Design Project (Phase 4)	Monday of week 12, ***at 11:00 a.m. EST***	14.4%	ALL UDLEs	ALL CLOs
Final Exam (Proctored)	Final exam period; Exact time TBA	50%	ALL UDLEs	ALL CLOs
Attendance	Sampled randomly throughout semester, at the discretion of the instructor	2%	UDLEs 1,2,3,4,5	CLO 1,2,3,4
	Total	100%		

[1] As per "Guidelines for University Undergraduate Degree Level Expectations," December 5, 2015. *http://www.queensu.ca/ctl/what-we-do/learning-outcomes-coursecurriculum-design-and-review/queens-new-quality-assurance*

Attendance

Students must attend all lectures and all labs throughout the term, though attendance at tutorials is optional. Lectures will be subject to random sampling of attendance at the discretion of the instructor, and the 2% attendance grade will be based on the sample attendance checks. Students must inform the instructor and/or the lead TA BEFORE a class in case of a medical or family emergency which prevents them from attending, so that alternative accommodations can be arranged. There will be no exceptions to this rule.

Group Project

More information about the Group Project can be found on Project Instructions, which is posted on D2L. It will be discussed in detail in lectures and labs as the year progresses.

Final Examination

The date, time and location of the Final Examination will be announced through SOLUS. The Final Exam is closed book; however, a formula sheet will be provided.

Course materials

Required textbook

- Shigley's Mechanical Engineering Design, 10th ed. Budynas & Nisbett., McGraw-Hill ISBN-10 0073398209, ISBN-13 9780073398204

The textbook is available from the Campus Bookstore. Note that three copies of the custom textbook have been placed on reserve in the Stauffer Library on Queen's campus.

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

- Machine Design – An Integran Approach, 4th ed. Norton, Prentice Hall ISBN-10 0136123708, ISBN-13 9780136123705

Other material

All other course material is accessible via D2L.

Timetable

Week	Learning Outcomes (with alignment to CLOs shown in square brackets)	Deliverable (with alignment to CLOs shown in square brackets)
1	**Course introduction & review of solid mechanics** After completing this module, students will be able to: • Explain the fundamentals of solid mechanics, as outlined in MECH 321 • Explain mathematical relationships among gear ratio, number of teeth, torque ratio, and angular velocity ratio for mating gears.	
2	**Introduction to Gears** After completing this module, students will be able to: • Determine all forces acting on 1-stage and 2-stage gears, and draw a complete free body diagram that show all external forces and torques in each case. • Be familiar with the basic functions of NX CAD software	
3	**Strength & Static Failure** After completing this module, students will be able to: • Explain the concepts behind and physical implications of the engineering definitions of mechanical stress, strength, and static failure	**Lab 1 [CLO 3]**
4-5	**Fatigue** After completing this module, students will be able to: • Explain the implications of cyclical loading & fatigue behavior for brittle and ductile materials • Design machine components to account for endurance limits and anticipated static and/or dynamic fatigue loading	**Lab 2 [CLO 3]** **Project Phase 1 [CLO 2,4,5]**
6-7	**Dynamics of gears** After completing this module, students will be able to: • Explain advanced topics regarding the dynamics and failure modes of gears, based on parameters outlined by the AGMA (American Gear Manufacturers Association) standards	**Project Phase 1 [CLO 2,4,5]**

Week	Learning Outcomes (with alignment to CLOs shown in square brackets)	Deliverable (with alignment to CLOs shown in square brackets)
	• Define a problem in detail • Concisely and effectively communicate engineering ideas in technical reports • Plan projects, while anticipating and mitigating potential risks effectively	
8	**Stress Analysis** After completing this module, students will be able to: • Predict stress distributions in simple beams subject to axial, bending, shear, and torsion loads • Effectively estimate realistic load cases for gears in various circumstances	**Project Phase 2 [CLO 1,3,4]**
9	**Shaft Design** After completing this module, students will be able to: • Explain stresses and loading conditions in shafts, and associated appropriate design considerations • Design gears for given real world load cases	**Project Phase 2 [CLO 1,3,4]**
10	**Rapid Prototyping** After completing this module, students will be able to: • Explain complexities associated with additive manufacturing process • Effectively implement additive manufacturing for rapid prototyping and testing of new designs • Plan and modify projects to deal with unforeseen circumstances effectively	**Project Phase 3 [CLO 1,2,4,5]**
11	**Bearings** After completing this module, students will be able to: • Identify a wide variety of bearings that are commonly used in machines, along with the sorts of loads for which they are applicable • Design prototypes for rapid testing, without compromising design quality	**Project Phase 3 [CLO 1,2,4,5]** **Project Phase 4 [CLO 1,4,5]**
12	**Intro to Finite Element Analysis** After completing this module, students will be able to: • Explain the general principles behind finite element analysis, and associated potential applications	**Project Phase 4 [CLO 1,4,5]**

Week	Learning Outcomes (with alignment to CLOs shown in square brackets)	Deliverable (with alignment to CLOs shown in square brackets)
13	**Final Exam** After completing this module, students will be able to: • Explain failure theories due to static loading • Explain failure theories due to dynamic loading (fatigue theories) • Explain mathematical relationships among gear ratio, number of teeth, torque ratio, and angular velocity ratio for mating gears • Determine optimum gear ratio, calculate the number of gear teeth, and choose proper pressure angle and module which does not generate gear interference • Determine all forces acting on 1-stage and 2-stage gears, and draw a complete free body diagram that show all external forces and torques in each case • Calculate safety factor of a gear with respect to fatigue failure due to bending and contact loading, according to the AGMA (American Gear Manufacturers Associations) standards • Determine stress concentration factors for various shaft geometries under static and dynamic loading • Calculate safety factor of a shaft with respect to fatigue failure due to bending moment and torsion • Explain various types of bearings and calculate bearing rating life under combined radial and thrust loading	**Final Exam** **[All CLOs]**

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 any 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.