MECH 478 / 578
Internal Combustion Engines
2019W2 Course Syllabus

~~Monday, Wednesday, Friday: 2-3pm, MCLD 254~~
Recorded lectures via Canvas
Weekly Discussion sessions via Collaborate Ultra (on Canvas)

Instructor

Patrick Kirchen
Office: CEME 2062
Email: pkirchen@mech.ubc.ca
Office Hours: ~~Wednesday, 3:00pm-4:00pm~~ or **by email**

Teaching Assistant

Elizabeth Trudel
Email: eliztrud@mail.ubc.ca
Office Hours: By appointment

COURSE MATERIALS ARE AVAILABLE ON CANVAS (canvas.ubc.ca)

Course Outline

1. Introduction
   1.1. Engine types and configurations
   1.2. History of engines, modern developments
   1.3. Challenges facing internal combustion engines
2. Review of Relevant Thermodynamics and Combustion Chemistry
   2.1. 1st law, modes of heat transfer, gas properties
   2.2. Equilibrium, stoichiometry, chemical kinetics, Arrhenius rate
   2.3. Fuel chemistry
   2.4. Emissions
   2.5. Engine performance metrics
3. Spark Ignition Engines
   3.1. Operating principle, standard cycles
   3.2. Combustion in SI engines, knocking
   3.3. SI engine emissions and emission control
   3.4. Control of SI engines, effect of throttling
4. Compression Ignition (Diesel) Engines
   4.1. Operating principle, cycles
   4.2. Combustion in diesel engines
   4.3. Diesel engine emissions and emission control
   4.4. Control of CI engines
5. Additional topics (flexible, depends on time available)
   5.1. Turbo/supercharging
   5.2. Alternative engine cycles (xCCI, GDI, stratified, downsizing)
   5.3. Alternative fuels

Learning Objectives

This course will provide students with a technical introduction to internal combustion engines and an overview of the current state of the art engine and emission control technologies. Students will apply engineering fundamentals (primarily thermodynamics, chemistry, and fluid mechanics) to the analysis and interpretation of modern reciprocating internal combustion engines. The factors governing engine design decisions will be discussed, as will alternative thermodynamic, combustion, and fuelling strategies.

By the end of MECH 478/578, students are expected to be able to:

- Apply concepts of mass and energy conservation, thermochemistry, combustion, heat transfer, and fluid dynamics for the analysis of internal combustion engines
- Calculate key metrics used for the characterization of the engines and their operation
- Identify the environmental, legislative, and technical constraints relevant to engine design and fuel selection decisions
- Explain the operating principles of systems used for controlling modern diesel and gasoline engines, and their emission control systems

Evaluation Criteria

Students will be evaluated on their ability to apply engineering fundamentals to the analysis of internal combustion engines and their demonstrated understanding of the current state of the art in engine technology and future trends. Assignments will include design-type questions to asses these abilities. Students are strongly encouraged to complete all assignments, as the numerical tools (e.g. Matlab or Excel) developed in earlier assignments are needed for later assignments.

Students enrolled in MECH 578 will complete a term project including a report ~~and presentation~~ focussing on a topic relevant to internal combustion engines. This topic can be assigned by the instructor or proposed by the student (pending instructor approval). Exams and assignments will be slightly different for 478 and 578. **Due to numerous 578 students travelling with uncertain timelines, presentations will not be held. The full 15% course weight will be assigned to the project report.**

Grade Weighting

MECH 478		**MECH 578**	
Assignments (4-5)	30%	Assignments (4-5)	15%
Midterm	30%	Project ~~and presentation~~	15%
Final	40%	Midterm	30%
		Final	40%

NOTE: In undergraduate MECH courses where at least 50% of the final grade is assigned to examinations, students may only **pass the course if they achieve a weighted average examination grade of at least 50%**. The "examination grade" includes scores from the final examination, midterms, and other tests done individually in a classroom setting. This policy applies unless it is explicitly waived by the instructor in the course syllabus. This policy is also available in the *Vancouver Academic Calendar* at http://www.calendar.ubc.ca/vancouver/index.cfm?tree=12,195,272,43.

Textbook (optional)

The textbook for MECH 478/578 will serve primarily as a reference for assigned reading and background information to complement in the in-class notes. Either of the two textbooks listed below can be used for the course and a reading list will be provided for both:

Internal Combustion Engine Fundamentals. John Heywood. McGraw Hill, 2018. 2nd edition.
Available in bookstore. This is an excellent reference for engines and is strongly recommended.

OR

Introduction to Internal Combustion Engines. Richard Stone. Macmillan Press, 2012
Available online at http://books.sae.org/book-r-391/
$US 120-140 with shipping (depending on SAE membership status), group order discounts available.

In addition, a thermodynamics textbook will be helpful for reference and property tables (e.g., Thermodynamics: An Engineering Approach. Y. Çengel and M. Boles. 7th edition).

Additional references and readings will be provided throughout the term, either as handouts or as sections in online textbooks available through UBC libraries. To access these, you will need to be on campus or connected to the UBC network via VPN.

Academic Integrity

The academic enterprise is founded on honesty, civility, and integrity. As members of this enterprise, all students are expected to know, understand, and follow the codes of conduct regarding academic integrity. At the most basic level, this means submitting only original work done by you and acknowledging all sources of information or ideas and attributing them to others as required. This also means you should not cheat, copy, or mislead others about what is your work. Violations of academic integrity (i.e., misconduct) lead to the breakdown of the academic enterprise, and therefore serious consequences arise and harsh sanctions are imposed. For example, incidences of plagiarism or cheating may result in a mark of zero on the assignment or exam and more serious consequences may apply if the matter is referred to the President's Advisory Committee on Student Discipline. Careful records are kept in order to monitor and prevent recurrences. Further information can be found in the UBC Calendar at:

http://www.calendar.ubc.ca/Vancouver/index.cfm?tree=3,54,111,959

The consequences of academic misconduct can range from a grade of zero on the work in question, to expulsion from your program. It is your responsibility to read, understand and abide by these regulations. Note that plagiarism detection tools are used on submitted projects and reports (UBC uses turnitin.com). If it is not clear to you what constitutes plagiarism, it is your responsibility to review the above calendar section and/or consult the course instructor – *prior to submitting work*.

Late Policy

Assignments are due at the beginning of class on the due date. After this, the following penalties will apply: -10% if received by the end of the day, -25% if received one day after due date, -35% if received two days after due date. Assignments received three or more days after due date will not be graded. Late assignments will be excused, or extensions granted for special circumstances (medical reasons, emergencies, etc.) if requested in advance of the due date.

Policies and Resources to Support Student Success

UBC provides resources to support student learning and to maintain healthy lifestyles but recognizes that sometimes crises arise and so there are additional resources to access including those for survivors of sexual violence. UBC values respect for the person and ideas of all members of the academic community. Harassment and discrimination are not tolerated nor is suppression of academic freedom. UBC provides appropriate accommodation for students with disabilities and for religious and cultural observances. UBC values academic

honesty and students are expected to acknowledge the ideas generated by others and to uphold the highest academic standards in all of their actions. Details of the policies and how to access support are available at https://senate.ubc.ca/policies-resources-support-student-success. Mechanical Engineering also has a Student Services Office (students@mech.ubc.ca), located in CEME 2205, where there are staff who can provide support and refer students to the appropriate resources.

Inclusive Environment

The Department of Mechanical Engineering is committed to providing an inclusive learning experience, and affirms the UBC Statement on Respectful Environment (https://www.hr.ubc.ca/respectful-environment/files/UBC-Statement-on-Respectful-Environment-2014.pdf). You are encouraged to contact their instructor should situations arise that are not consistent with this expectation. You are also invited to advise the instructor if you wish to be addressed by or referred to with particular pronouns.

Additional References

These references are provided for additional reading if you are so inclined. They are not required for MECH 478/578 but will be useful in providing more information than is possible during the lectures. This is by no means an exhaustive list but will provide you with a starting point for finding additional information.

Books:

- Combustion Engines Development: Mixture Formation, Combustion, Emissions and Simulation. Günter P. Merker, Christian Schwarz, Rüdiger Teichmann. 2012.
  http://link.springer.com/book/10.1007%2F978-3-642-14094-5#section=961643&page=1&locus=3
  A general textbook covering the development of modern engines
- Internal Combustion Engine Handbook - Basics, Components, Systems, and Perspectives. Richard van Basshuysen, Fred Schäfer. 2004.
  http://app.knovel.com/web/toc.v/cid:kpICEHBCS1/viewerType:toc/root_slug:internal-combustion-engine-3/url_slug:internal-combustion-engine-3/
  A comprehensive handbook covering a broad range of engine topics.
- Flow and Combustion in Reciprocating Engines. C. Arcoumanis, T. Kamimoto. 2009.
  http://site.ebrary.com/lib/ubc/docDetail.action?docID=10313458
  Deals with the flow and combustion processes within the cylinders of engines.
- Handbook of Diesel Engines. K. Mollenhauer, H. Tschöke. 2010.
  http://link.springer.com/book/10.1007/978-3-540-89083-6/page/1
  A textbook dealing with modern diesel engines, including peripheral systems
- Charging the Internal Combustion Engine. H. Hiereth, P. Prenninger. 2007.
  http://link.springer.com/book/10.1007/978-3-211-47113-5/page/1
  Focusses on super- and turbocharging internal combustion engines.
- An Introduction to Engine Testing and Development. R. Atkins. 2009.
  http://app.knovel.com/web/toc.v/cid:kpAIETD006/viewerType:toc/root_slug:an-introduction-engine/url_slug:an-introduction-engine/?
  Provides information for developing and carrying out engine experiments.
- Mixture Formation in Internal Combustion Engines. C. Baumgartner. 2006.
  http://link.springer.com/book/10.1007/3-540-30836-9
  A dedicated text discussing in-cylinder mixture formation, an important topic for direct injection engines
- Introduction to Modeling and Control of Internal Combustion Engine Systems. L. Guzzella, C. Onder. 2010.
  http://link.springer.com/book/10.1007/978-3-642-10775-7/page/1

A useful reference for understanding the underlying processes of engine control and the associated models. Some knowledge of control systems is needed.

- Vehicular Engine Design. K. Hoag. 2006.
  http://link.springer.com/book/10.1007/3-211-37762-X/page/1
  Provides guidance for the practical design of engine for vehicular applications.
- Combustion: Physical and Chemical Fundamentals, Modeling and Simulation, Experiments, Pollutant Formation. J. Warnatz, U. Maas, R. Dibble. 2001.
  http://link.springer.com/book/10.1007/978-3-662-04508-4/page/1
  A concise introduction to combustion theory, with some examples linked to engines.
- Combustion. I. Glassman. 2006.
  http://site.ebrary.com/lib/ubc/docDetail.action?docID=10216698
  A comprehensive reference for combustion fundamentals.
- Biodiesel: Production and Properties. A. Sarin. 2012.
  http://site.ebrary.com/lib/ubc/docDetail.action?docID=10655136
  An overview of the production and use of diesel fuel derived from biological (plant) sources.

Journals, Periodicals, Trade Publications:

- Society of Automotive Engineers, Mobilus
  http://ezproxy.library.ubc.ca/login?url=http://digitallibrary.sae.org/advanced
  Database of all SAE publications. A very useful resource for technical papers and standards
- International Journal of Engine Research
  http://journals.sagepub.com/loi/jera
  Peer reviewed journal for engine research
- ATZ Worldwide
  http://link.springer.com/journal/38311
  Trade magazine for automobile technology
- MTZ Worldwide
  http://link.springer.com/journal/38313
  Trade magazine for engine technology
- MTZ Industrial
  http://link.springer.com/journal/40353
  Trade magazine of the International Council on Combustion Engines (CIMAC); focusses on engines with cylinder displacements >2 L