Faculty of Engineering and Applied Science

CHEE 210 – Thermodynamics of Energy Conversion Systems Course Syllabus – Winter 2022

This is your course syllabus. Please download the file and keep it for future reference.

LAND ACKNOWLEDGEMENT

Queen's University is situated on traditional Anishinaabe and Haudenosaunee Territory.
See: http://www.queensu.ca/encyclopedia/t/traditional-territories

INCLUSIVITY STATEMENT

Queen's students, faculty, and staff come from every imaginable background – small towns and suburbs, urban high rises, Indigenous communities, and from more than 100 countries around the world. You belong here: https://www.queensu.ca/inclusive/.

TEACHING TEAM

COURSE INSTRUCTOR

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CHEE 210 (F 3-0-0.5 3.5)

COURSE DESCRIPTION[1]

This course is an introduction to thermodynamics for chemical engineering systems analysis. The principles arising from First and Second laws of thermodynamics will be applied to the solution of mass, energy, and entropy balances for homogeneous closed and open systems. Properties of ideal gases and real fluids will be derived from Equations of State and applied in the analysis of simple flow processes. The students will compute efficiencies and coefficients of performance for energy production, conversion, and storage systems. The impacts of energy process design choices on efficiency, performance, and sustainability will be measured through exergy analysis. (0/0/0/42/0).

Prerequisites CHEE 221 (or MINE 201).

(0/0/0/42/0) (Mathematics/Natural Sciences/Complementary Studies/Engineering Science/Engineering Design)

PRE-REQUISITE KNOWLEDGE

This course is designed for learners with some background on mass and energy balance laws and some knowledge of energy from physics.

COURSE LEARNING OUTCOMES (CLO)

This course reinforces the concept of mass and energy balances viewed in CHEE 221 (or MINE 201) by applying the First and Second laws of thermodynamics to closed and open systems. Consequences of thermodynamics in the computation of real fluid quantities in the analysis of key process components are derived. Thermodynamic efficiency and coefficient of performance are used in the analysis of energy production, conversion, and storage processes. Thermodynamic analysis is developed for gas, steam, combined cycles, as well as refrigeration systems and air conditioning. Impacts of design choices and operation conditions on efficiency and performance are emphasized, with the aim of improving energy processes sustainability.

[1] Course Author(s): Nicolas Hudon. 1st Edition (initial development): Winter 2017; Queen's University holds a license for the use of the Course Author's Intellectual Property for CHEE 210.

The specific course learning outcomes include:

CLO	DESCRIPTION	INDICATORS
CLO 1	Apply the fundamental concepts of thermodynamics to solve material, energy, and entropy balances for process components, open or closed.	**KB-Thermo(a) PA-Formulate**
CLO 2	Apply the First Law of Thermodynamics to compute heat, work, and changes in internal energy and enthalpy for the analysis of open or closed homogeneous systems undergoing reversible or irreversible processes.	**KB-Thermo(a) PA-Formulate**
CLO 3	Apply the Second Law of Thermodynamics and the concept of entropy production to the analysis of reversible or irreversible processes.	**KB-Thermo(a) PA-Formulate**
CLO 4	Establish the relationships between internal energy, enthalpy, entropy, Gibbs and Helmholtz free energies potentials. Relate these potentials to heat capacities, measurable variables, and macroscopic quantities. Use Maxwell's relations.	**KB-Thermo(a)**
CLO 5	Use equations of state for gases and liquids to determine changes in properties of fluids and apply these equations to solve material, energy, and entropy balances for process components, open or closed.	**KB-Thermo(a) KB-Thermo(b)**
CLO 6	Describe and analyze the performance and efficiency of simple engines, Rankine cycles, Brayton cycles, and refrigeration cycles. Apply the combined material, energy, entropy, and exergy balance equations to solve process flow problems.	**KB-Thermo(b) PA-Formulate**

The course outcomes are mapped to the following program indicators at a 2nd year level:
Knowledge Base for Engineering (KB):

KB-Thermo(a) Applies laws of thermodynamics, identifies thermodynamic and PVT properties and applies equations of state to describe fluid behaviour and construct phase diagrams for single and multi-component systems
KB-Thermo(b) Analyzes thermodynamic cycles and process components and performs the relevant calculations
Problem Analysis (CLO 4):

PA-Formulate Develop appropriate frameworks for solving complex engineering problems.

RELEVANCE TO THE PROGRAM

- The course expands the notion of mass and energy balances introduced in CHEE 221 and developed concurrently in CHEE 222 by introducing the First and Second laws of thermodynamics in the analysis of simple chemical processes, with an emphasis on energy production, conversion, and storage systems.
- A rigorous formulation of thermodynamic concepts and property of fluids is developed as a pre-requisite to CHEE 311 where the concepts of thermal, mechanical, and chemical equilibrium are developed further. The concepts arising from this thermodynamic framework will also be used in CHEE 321.
- Impacts of design choices on efficiency and performance and thermodynamic limitations in the design of energy conversion systems introduced in this course will be reinforced in CHEE 330.

COURSE STRUCTURE AND ACTIVITIES

- Three (3) lecture hours: Monday 9:30; Wednesday 3:30; Wednesday 4:30.
- One (1) tutorial hour: Friday 1:30.
- Virtual office hours: Tuesday 12:30; Thursday 12:30; Friday 2:30.

The lectures and tutorial will be delivered on Zoom. Only the tutorial will be systematically recorded and posted on OnQ.

The zoom links are as follows:

Monday 9:30 (1 hour lecture): Meeting ID: 980 2204 7205; Passcode: 274029
Tuesday 12:30 (Virtual office hours): Meeting ID: 919 6498 4135; Passcode: 394862
Wednesday 3:30 (2 hours lecture): Meeting ID: 950 6395 4566; Passcode: 825538
Thursday 12:30 (Virtual office hours): 944 7587 4932; Passcode: 957773
Friday 1:30 (1 hour tutorial and office hours): Meeting ID: 929 6001 2094; Passcode: 786517

- A weekly summary, practice problems set, will be posted on Mondays on OnQ.
- Videos for theory (derivations) and examples will be made available on OnQ early in the week and discussed during the Wednesday lecture.
- Solutions to the weekly problems set will be posted on Fridays on OnQ.
- Lectures will not be recorded systematically. Office hours will not be recorded and students are asked to come with questions.

EXPECTATIONS FOR LECTURES/TUTORIALS

This course contains concepts that are inherently difficult to grasp. However, the emphasis of the course resides in the application of the concepts to energy processes ranging from simple to complex. The problem-solving approach enforced during the course might seem a heavy burden for simple problems, but becomes handy as the problems complexity grows.

Students are encouraged to make use of all resources available, including suggested readings, tutorials, on-line videos, and solved problems available on OnQ. Students are expected to implement methods taught in class to tackle a variety of problems that they may encounter in suggested problems/midterm/final exam.

COURSE EVALUATION

ASSESSMENT WEIGHTING

Assessment Tool	Due Date	Weight	Alignment with CLOs
Midterm	**Week 8**	**30%**	**1, 2, 3, 4, 5**
Project	**Week 12**	**20%**	**1, 2, 3, 4,5,6**
Final	**Final Exams Period**	**50%**	**1, 2, 3, 4, 5,6**

Assessment Tool	Due Date	Weight	Alignment with CLOs
		100%	

Unless other arrangements have been approved, departmental policies regarding late and missed assignments, and missed quizzes/exams will be followed.

ASSESSMENT DESCRIPTIONS

Midterm

There is one midterm in this course. This midterm is designed to test the fundamental understanding of students on mass, energy, and entropy balances for closed and open systems. As the problems are to be applied to fluids modeled by ideal and non-ideal constitutive laws, a deep understanding of the mathematical structure of equilibrium thermodynamics is required by the students. The midterm duration will be of 2 hours.

Project

There is a project in this course, to be presented to students in Week 8 and to be finalized by the students (in groups of 3 or 4) by the end of week 12. He objective is for the students to study, analyse, and improve an energy cycle using all the methods and theory presented in the course.

Final Exam

The final exam is open book. Students must write their exam on the day and time scheduled by the University. You should not schedule vacations, travel, etc. during the exam period. The Term and Session Dates will indicate the final exam period session dates in each term.

Remote Proctoring - Proctortrack

The final exam and the midterm in this course might use remote proctoring provided by a third-party, cloud-based service that enables the completion of a proctored exam or test from an off-campus location, through onQ or Elentra. This online proctoring solution was chosen as part of the approach to maintaining academic integrity in online assessment. Precise details about how remote proctoring will be used in this course can be found in the "Getting Started with Remote Proctoring" content module in onQ. When writing tests/exams using remote proctoring, you are connecting to the third-party service. Queen's has conducted a privacy and security review of the service and has entered into a binding agreement with terms that address the appropriate collection, use and disclosure of personal information in accordance with Ontario's privacy legislation. You should also take measures yourself to protect your information by keeping your NetID password and challenge questions private, closing all applications prior to starting an exam/test, and ensuring your device is updated and safeguarded against malware. For more information about remote proctoring, see the Student FAQs on the VPTL/ITS Resource page for remote proctoring.

GRADING

All assessments in this course will receive numerical percentage marks. The final grade you receive for the course will be derived by converting your numerical course average to a letter grade according to the established Grade Point Index.

Feedback on Assessments

The teaching team will provide feedback on graded activities. You can expect feedback on your assessments within ten days of the due date.

Accessing Your Final Grade

Your final grades will show on SOLUS. Official transcripts showing final grades will be available on the Official Grade Release Date. Please note that in official transcripts, a mark of IN (incomplete) is considered a grade, and your transcript is released with this grade.

COURSE MATERIALS

Suggested Textbooks (Optional)

- Y.A. Cengel and M.A. Boles (2019). Thermodynamics: An Engineering Approach, 9th Ed. McGraw-Hill, NY.
- K.D. Dahm and D.P. Visco Jr. (2015). Fundamentals of Chemical Engineering Thermodynamics. Cengage Learning.
- S.I. Sandler (2017). Chemical, Biochemical, and Engineering Thermodynamics. 5th Ed. Wiley
- H. Struchtrup (2014). Thermodynamics and Energy Conversion. Springer-Verlag, Berlin. Online

Course notes and other course-related material

All other course material is accessible via OnQ.

Required Calculator

- A Casio 991 is required. **ONLY** this type of non-programmable, non-communicating calculator will be allowed during tests and exams.

Required Hardware/Software

Students must have a reliable internet connection and hardware that are compatible with online learning and remote proctoring system requirements.

Course Specific Computer-Related Skills

This course requires no computer-related technical skills, apart from a basic knowledge of Matlab for the project. For this course, you may also need to use the Maple software that is available to all students at Queen's. This software is available on the desktop computers in the computer labs, which means that you will need to connect to the software through the Queen's Virtual Desktop. Follow the link for details on how to set up this connection.

Suggested Time Commitment

This course represents a study period of one semester spanning 12 weeks. Learners can expect to invest on average 7-10 hours per week in this course. Learners who adhere to a pre-determined study schedule are more likely to successfully complete the course.

WEEKLY COURSE OUTCOMES

Week	Learning Outcomes	Assessment
1	**Thermodynamic Systems, Variables, and Conservation Laws** By the end of this week, learners will be able to: • Distinguish extensive and intensive variables; closed and open systems. [CLO1] • Develop, adapt, and balance equations for extensive quantities. [CLO1]	
2	**Energy, Heat, and Work: The First Law of Thermodynamics** By the end of this week, learners will be able to: • Apply the First law of thermodynamics to closed and open systems using mass and energy balance equations. [CLO1], [CLO2]	
3	**Entropy and Entropy Balances: The Second Law of Thermodynamics** By the end of this week, learners will be able to: • Apply the Second law of thermodynamics to closed and open systems using mass and energy balance equations. [CLO1], [CLO3]	
4	**Elementary Processes for Ideal Gases; Combined Mass, Energy, and Entropy Balances** By the end of this week, learners will be able to: • Develop mass, energy, and entropy balances for simple open and closed processes for ideal gases [CLO1], [CLO2], [CLO3] • Determine if a process is thermodynamically feasible or not [CLO1],[CLO2],[CLO3]	
5	**Thermodynamics Mathematical Formalism** By the end of this week, learners will be able to: • Establish the relationships between thermodynamic potentials and develop expressions for physical quantities in terms of observable quantities. [CLO4]	

Week	Learning Outcomes	Assessment
6	**Properties of Fluids and Equations of State** By the end of this week, learners will be able to: • Use Equations of State for different non-ideal fluids to develop expressions to compute internal energy, enthalpy, and entropy changes and use these expressions to solve systems of balance equations for closed and opened systems [CLO1], [CLO2], [CLO3], [CLO4], [CLO5]	
7	**Equilibrium and Stability; Gibbs Phase Rule; Critical State; Corresponding State** By the end of this week, learners will be able to: • Apply the Gibbs phase rule. [CLO5] • Apply the concept of corresponding state to compute internal energy, enthalpy, and entropy changes and use these expressions to solve systems of balance equations for closed and opened systems [CLO1], [CLO2], [CLO3], [CLO4], [CLO5]	Midterm [CLO1], [CLO2], [CLO3], [CLO4], [CLO5]
8	**Exergy, Performance and Efficiency** By the end of this week, learners will be able to: • Compute exergy content and exergy variations for closed and open systems and use the concept to compute performance and efficiency. [CLO6]	
9	**Combustion, Engines, and Gas Cycles** By the end of this week, learners will be able to: • Perform combustion calculations [CLO6] • Describe and analyze gas cycles and discuss their efficiency. [CLO6]	
10	**Steam Cycles, Geothermal Cycles, and Combined Cycles** By the end of this week, learners will be able to: • Describe and analyze steam cycles, including geomethermal, and discuss their efficiency. [CLO6]	

Week	Learning Outcomes	Assessment
11	**Refrigeration and Air Conditioning** By the end of this week, learners will be able to: • Describe and analyze refrigeration cycles and heat pumps and discuss their performance. [CLO6] • Describe and analyze air conditioning units and their discuss their efficiency. [CLO3], [CLO6]	
12	**Energy Storage and Sustainability** By the end of this week, learners will be able to: • Use the concepts of efficiency and performance to analyze energy storage systems. [CLO3], [CLO6] • Use the concept of exergy to improve and optimize sustainable energy systems. [CLO3], [CLO6]	Project [CLO1], [CLO2], [CLO3], [CLO4], [CLO5], [CLO6] Final[CLO1], [CLO2], [CLO3], [CLO4], [CLO5], [CLO6]

COURSE COMMUNICATION

NETIQUETTE

In this course, you may be expected to communicate with your peers and the teaching team through electronic communication. You are expected to use the utmost respect in your dealings with your colleagues or when participating in activities, discussions, and online communication.

Following is a list of netiquette guidelines. Please read them carefully and use them to guide your online communication in this course and beyond.

1. Make a personal commitment to learn about, understand, and support your peers.
2. Assume the best of others and expect the best of them.
3. Acknowledge the impact of oppression on the lives of other people and make sure your writing is respectful and inclusive.
4. Recognize and value the experiences, abilities, and knowledge each person brings.
5. Pay close attention to what your peers write before you respond. Think through and re-read your writings before you post or send them to others.
6. It's alright to disagree with ideas, but do not make personal attacks.
7. Be open to be challenged or confronted on your ideas and challenge others with the intent of facilitating growth. Do not demean or embarrass others.
8. Encourage others to develop and share their ideas.

QUESTIONS ABOUT COURSE MATERIAL

Questions or comments regarding the course material that can be of benefit to other students should be asked at the end of each virtual lecture or during the intructor's virtual office hours.

COURSE ANNOUNCEMENTS

The instructor will routinely post course news in the Announcements section on the main course homepage on OnQ. Please sign up to be automatically notified by email when the instructor posts new information in the Announcements section. Instructions on how to modify your notifications are found in the **Begin Here** section of the class website.

OFFICE HOURS

You will have the opportunity to interact in a synchronous fashion with either a TA or the instructor through office hours. The instructor will provide a schedule of availability at the beginning of the term.

CONFIDENTIAL MATTERS

If you have a confidential matter you would like to discuss with your instructor, their contact details are on the first page of this document. Expect email replies within 24 hours.

RECORDING SYNCHRONOUS (LIVE) CLASSES

Synchronous (live) classes will be delivered in this course through a video conferencing platform supported by the University [Zoom]. Steps have been taken by the University to configure these platforms in a secure manner, and to maintain student privacy while delivering courses remotely. Please note the following:

- Lectures **will not** be recorded with video and audio (and in some cases transcription) and **will not** be made available to students in the course for the duration of the term.
- Tutorials **will not** have mandatory participation, and **will** be recorded with video and audio and will be made available to students in the course for the duration of the term.

The recordings may capture your name, image or voice through the video and audio recordings. By attending these live classes, you are consenting to the collection of this information for the purposes of administering the class and associated coursework. If you are concerned about the collection of your name and other personal information in the class, please contact the course instructor to identify possible alternatives.

To learn more about how your personal information is collected, used and disclosed by Queen's University, please see the general Notice of Collection, Use and Disclosure of Personal Information.

STANDARD FEAS INFORMATION

COURSE POLICIES

Please review the following policies concerning copyright, academic integrity, absences and academic accommodations:

COPYRIGHT

Course materials created by the course instructor, including all slides, presentations, synchronous and asynchronous course recordings, handouts, tests, exams, and other similar course materials, are the intellectual property of the instructor. It is a departure from academic integrity to distribute, publicly post, sell or otherwise disseminate an instructor's course materials or to provide an instructor's course materials to anyone else for distribution, posting, sale or other means of dissemination, without the instructor's ***express consent***. A student who engages in such conduct may be subject to penalty for a departure from academic integrity and may also face adverse legal consequences for infringement of intellectual property rights and, with respect to recordings, potentially privacy violations of other students.

ACADEMIC INTEGRITY

As an engineering student, 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. Please note that 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

The standard of behaviour expected of professional engineers is explained in the Professional Engineers Ontario Code of Ethics. Information on policies concerning academic integrity is available in the Queen's University Code of Conduct, in the Senate Academic Integrity Policy Statement, on the Faculty of Engineering and Applied Science website, and from your instructor.

Departures from academic integrity include plagiarism, use of unauthorized materials or services, facilitation, forgery, falsification, unauthorized use of intellectual property, and collaboration, and are antithetical to the development of an academic community at Queen's. Given the seriousness of these matters, actions which contravene the regulation on academic integrity carry sanctions that can range from a warning or the loss of grades on an assignment to the failure of a course to a requirement to withdraw from the University.

In the case of online or remotely proctored exams, impersonating another student, copying from another student, making information available to another student about the exam questions or possible answers, posting materials to online services, communicating with another person during an exam or about an exam during the exam window, or accessing unauthorized materials, including internet sources and using unauthorized materials, including smart devices, are actions in contravention of academic integrity.

Late Policy

Any applicable late penalties are described in the details for each assessment. In the event of extenuating circumstances, you must follow the policies for requesting an academic consideration (please see below). Note that unacceptable reasons include extra-curricular activities, travel plans, being generally behind on schoolwork, etc. In the absence of an approved consideration request, the normal late penalty will apply as described in the assignment or any course/departmental policies.

Invalid Exams

An exam may be declared invalid in case of an interruption in an in-person examination; if the instructions in a remote or online exam were not followed; if the student uploads wrong materials; or if a situation arises where the integrity of the exam cannot be verified. If an exam is declared invalid, the student may be granted a re-write.

Absences (Academic Considerations) and Academic Accommodations

For absences and academic accommodations please review the information on the FEAS website.

ACADEMIC AND STUDENT SUPPORT

Queen's has a robust set of supports available to you including the Library, Student Academic Success Services (Learning Strategies and Writing Centre), and Career Services. Learners 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.

Individual Needs and Support

If you have a disability or health-related condition that may require academic accommodations, please approach the Queen's Accessibility Services. The staff at Accessibility Services are available by appointment to develop individualized accommodation plans, provide referrals, and assist with advocacy. The sooner you let us know your needs, the better we can assist you in achieving your learning goals. For questions or assistance with requesting Academic Consideration or Accommodation, contact the FEAS Academic Accommodation Coordinator at engineering.aac@queensu.ca

Every effort has been made to provide course materials that are accessible. For further information on accessibility compliance of the educational technologies used in this course, please consult the links below.

Educational Technology **(MODIFY THIS TABLE TO INCLUDE TOOLS USED IN YOUR COURSE)**	Accessibility Compliance Information
onQ (Brightspace Learning Management System by D2L)	https://www.d2l.com/accessibility/standards/
MS-Teams	https://support.microsoft.com/en-us/office/accessibility-support-for-microsoft-teams-d12ee53f-d15f-445e-be8d-f0ba2c5ee68f
Zoom	https://zoom.us/accessibility

If you find any element of this course difficult to access, please contact engineering.aac@queensu.ca

Accommodations Related to Remote Assessment

To have your accommodations applied to a remote-proctored exam please follow the instructions for submitting your information, as outlined on the QSAS website. Your accommodations will be incorporated

into your exam session by the Queen's University exam coordinators, on behalf of your course instructor. This information is uploaded automatically to Proctortrack / Examity.

If you are already registered with QSAS and you require additional accommodations related to remote-proctored exams, please consult with your QSAS advisor to update your Letter of Accommodation as appropriate.

Religious Observance

Students in need of accommodation for religious observance are asked to speak to their professor within a week of receiving their syllabus. Note also that alternative assignments are considered a "reasonable accommodation" under the Ontario Human Rights Code. Students with questions about their rights and responsibilities regarding religious accommodation should contact the Chaplain via Chaplain@queensu.ca.

Technical Support

Some basic comfort level with basic hardware and software skills are required for this course. If you require technical assistance, please contact Technical Support.

Supportive Personal Counselling

If at any time you find yourself feeling overwhelmed, anxious, sad, lonely, or distressed, consider confidential supportive counselling offered by the embedded counselors and by Student Wellness Services https://www.queensu.ca/studentwellness/