# MECH 330 – APPLIED THERMODYNAMICS II

## Course Syllabus – Fall 2024

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

**Francesco Ambrogi, PhD**
Department of Mechanical and
Materials Engineering

E-mail: francesco.ambrogi@queensu.ca
Office hours: By appointment

### Teaching Assistant

Please visit the OnQ page to know more about the teaching team.

# MECH 330 (F 3-0-0.5 3.5)

## Course Description

A continuation of MECH 230 with selected topics such as gas and vapour power cycles, refrigeration, mixtures of gases and vapours, combustion, and available energy.

Prerequisites: MECH 230 (Applied Thermodynamics I) or ENPH 274 (PHYS 274)
(0/0/0/42/0) (Mathematics/Natural Sciences/Complementary Studies/Engineering Science/Engineering Design)

## Pre-Requisite Knowledge

This course builds on knowledge from the successful completion of prerequisite courses, some review will be covered in first weeks of course.

## Course Learning Outcomes (CLO)

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

| CLO | Description | Indicator |
|---|---|---|
| CLO 1 | Calculate energy efficiency changes using re-heating, regeneration, use of open and closed feedwater heaters, and deaerators in vapour power systems (Vapour power) | KB-Engineering Science (Thermodynamics), PA – Identify, PA – Formulate, PA – Solve |
| CLO 2 | Calculate energy efficiency changes associated with regenerative heating through use of heat exchangers, re-heat and intercooling in gas power systems or Brayton Cycles (Gas power) | KB-Engineering Science (Thermodynamics), PA – Identify, PA – Formulate, PA – Solve |
| CLO 3 | Use exergy analysis to calculate energy availability and effectiveness (Exergy) | KB-Engineering Science (Thermodynamics), PA – Identify, PA – Formulate, PA – Solve |
| CLO 4 | Calculate the coefficients of performances of vapour compression and Brayton refrigeration cycles that use different working fluids with multistage compression and intercooling in refrigeration and heat pump systems (Refrigeration) | KB-Engineering Science (Thermodynamics), PA – Identify, PA – Formulate, PA – Solve |

| CLO | DESCRIPTION | INDICATOR |
|---|---|---|
| CLO 5 | Calculate thermodynamic properties of ideal gas mixtures, including gases that contain water vapour and apply the Psychrometric chart (Psychrometrics) | KB-Engineering Science (Thermodynamics), PA – Identify, PA – Formulate, PA – Solve |
| CLO 6 | Calculate the energy release from combustible mixtures, including the lower and higher heating values (Combustion) | KB-Engineering Science (Thermodynamics), PA – Identify, PA – Formulate, PA – Solve |

# COURSE EVALUATION

## ASSESSMENT WEIGHTING

| Assessment Tool | Due Date (Before 23:59 ET) | Weight | Alignment with CLOs |
|---|---|---|---|
| Assignments regular (5) | Assigned online via OnQ Best 4 out of 5 | 5% | 1, 2, 3, 4, 5, 6, 7 |
| Assignments jupyter (5) | Assigned online via OnQ Best 4 out of 5 | 15% | 1, 2, 3, 4, 5, 6, 7 |
| In-class Tests (2) | | 40% | 1, 2, 3, 4, 5, 6, 7 |
| Final Exam (Proctored) | **The student MUST pass the final to pass the course.** | 40% | 1, 2, 3, 4, 5, 6, 7 |
| | | 100% | |

## ASSESSMENT DESCRIPTIONS

### Assignments regular (5%)

There are 5 traditional assignments due approximately every other week, submitted electronically on onQ. The assignments will not be marked in detail, instead learners are encouraged to consult homework solutions posted on onQ for feedback. They will be reviewed for **original content** and graded as 2 – strong effort, 1 – moderate effort, and 0 – minimal effort or missing. The top 4 assignments will be used for the overall assignment mark (one will be dropped) to accommodate for extenuating circumstances. Students should aim to submit all assignments. Each student is responsible for completing their own assignments. Late assignments will not be accepted, except with documented accommodation or permission from the Faculty office.

## Assignments Jupyter (15%)

In addition to the traditional assignments, there will be 5 'Jupyter Assignments' which are assignments completed in a python-based Jupyter notebook. These assignments will tackle in-depth problems using the thermodynamic computational library Cantera, also submitted electronically on onQ. These assignments are designed to introduce learners to modern tools to model energy systems. A Jupyter notebook skeleton with questions and starter scripts will be provided for every assignment. Students may choose to work with one partner and submit a single assignment for both group members. Students may choose their own partner at the beginning of the term on onQ. Jupyter assignments will be graded in more detail than assignments. The top 4 Jupyter assignments will be used for the overall assignment mark to accommodate for extenuating circumstances. Late assignments will not be accepted, except with documented accommodation or permission from the Faculty office.

## In-Class Tests (40%)

There are 2 in-class tests throughout the course. Tests and the final exam will be closed book. You will be permitted a calculator and a single letter sized one-sided handwritten reference sheet for each test and a double-sided sheet of the same format for the final exam. **Rules to follow while preparing the formula sheet will be given by the instructor and posted on OnQ.** Students are responsible for checking their solutions against posted solutions in order to hone their problem-solving skills needed for tests and final exam. All components of 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 Queen's Official Grade Conversion Scale.

## Final Exam (40%)

The final exam is 3 hours long and is closed book. Students must work individually on the exam and must not cooperate in any way with anyone on the completion of the exam. **Students MUST PASS the final exam (>51%) to pass the course**. 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.

# 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 seven 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 Textbook

Fundamentals of Engineering Thermodynamics 9th Ed. by Moran, Shapiro, Boettner, and Bailey, Wiley. A paper copy or e-book is acceptable. The steam tables in the back of the book are needed to complete traditional assignments, and students should be comfortable working with these tables because they will also be used in exams (a copy of the tables will be provided in exams). An earlier edition is also ok, although there may be some mismatch between assigned reading.

### In-class Notes

Students are strongly encouraged to follow the 3-hours/weekly lectures and to take notes.

### Other Material

All other course material is accessible via OnQ. Attendance at lectures is strongly recommended as ONLY material covered in class will be included in the tests. The instructor will also post weekly readings (optional for the students) on Connect to help students familiarize with the material and be on track with the course content.

### Required Calculator

A Casio 991 is required. **ONLY** this type of non-programmable, non-communicating calculator will be allowed during tests and exams. This calculator sells for around 25 USD at the Queen's Campus Bookstore, Staples and other popular suppliers of school and office supplies.

### Suggested Time Commitment

Generally, we expect that students attend all lectures (3hrs/week), review material at home (1 hr/week), complete the weekly assignment problems (1-2 hrs/week - if an assignment takes much more than 1 hr you should be doing additional problems and coming to tutorials and office hours for additional help understanding, about another 2 hours a week). If you keep up your understanding week to week, then a few hours review should be enough to do well on the final exam. An average student will be able to do well in this course by spending about 6 hours a week, over the twelve-week term.

# WEEKLY COURSE LEARNING OUTCOMES

| Week | Learning Outcomes | Assessment |
|---|---|---|
| 1 | **Introduction**<br>Reading: Review Chapters 3-6; Supplemental handout entropy By the end of this week, learners will be able to:<br>• Understand the motivation for studying energy systems<br>• Recall MECH 230 (or equivalent) material | MP1, Midterm, Final |

| Week | Learning Outcomes | Assessment |
|---|---|---|
| 2 | **Vapor power systems** Reading: 8.1-8.2<br><br>By the end of this week, learners will be able to:<br><br>• Demonstrate basic understanding of vapour power systems and modifications including T-s diagrams, evaluating property data at principal states, apply mass, energy, and entropy balances, determine cycle performance, thermal efficiencies, net power output and mass flow rates | A1, MP2, Midterm 1, Final [CLO1] |
| 3 | **Vapor power systems continued** Reading: 8.3-8.4<br><br>By the end of this week, learners will be able to:<br><br>• Understand and analyze advanced vapor power system modifications such as reheat, superheat, and regeneration | A2, MP2, Midterm 1, Final [CLO1] |
| 4 | **Gas power systems** Reading: 9.5-9.6<br><br>By the end of this week, learners will be able to:<br><br>• Perform air standard analyses of gas turbine power cycles based on Brayton cycle including: T-s diagrams, evaluating property data at principal states; applying mass, energy, and entropy balances; determine net power output, thermal efficiency, back work ratios, and compressor pressure ratio | A2, MP3, Midterm 1, Final [CLO2] |
| 5 | **Gas power systems continued** Reading: 9.7, 9.8, 9.11<br><br>By the end of this week, learners will be able to:<br><br>• Perform more advanced analysis of gas turbine systems including regenerative gas turbines and gas turbines for aircraft propulsion | A3, MP3, Midterm 1, Final [CLO2] |
| 6 | **Available energy (exergy)** Reading: 7.1-7.6, 9.9<br><br>By the end of this week, learners will be able to:<br><br>• Perform exergy balances to closed systems and control volumes<br>• Define and calculate exergetic efficiencies | A3, Midterm 2, Final [CLO3] |

| Week | Learning Outcomes | Assessment |
|---|---|---|
| 7 | **Vapor-compression refrigeration**<br><br>Reading: 10.1-10.4<br>By the end of this week, learners will be able to:<br><br>• Develop and analyse thermodynamic models of vapour compression systems and their modifications, including T-s diagrams, property evaluation, applying mass, energy, entropy and exergy balances, COP | A3, Midterm 2, Final [CLO4] |
| 8 | **Advanced refrigeration and heat pumps** Reading: 10.5-10.7<br><br>By the end of this week, learners will be able to:<br><br>• Analyze thermodynamic models of absorption and gas- powered refrigeration and heat pumps. | MP4, Midterm 2, Final [CLO4] |
| 9 | **Psychometrics** Reading: 12.1-12.7<br><br>By the end of this week, learners will be able to:<br><br>• Ideal gas mixtures using molar and mass fractions<br>• Dalton model to calculate state properties<br>• Apply mass, momentum and energy involving gas<br><br>mixtures<br><br>• Humidity ratio, relative humidity, mixture enthalpy, dew<br><br>point temperatures<br><br>• Use psychrometric chart | A4, Midterm 2, Final [CLO5] |
| 10 | **Combustion** Reading: 13.1-13.3<br><br>By the end of this week, learners will be able to:<br><br>• Demonstrate understanding of key concepts of complete combustion, theoretical air, enthalpy of formation and adiabatic flame temperature<br>• Balance equations | A5, MP5, Final [CLO6] |

| Week | Learning Outcomes | Assessment |
|---|---|---|
| 11 | **Combustion continued** Reading: Lecture notes<br><br>By the end of this week, learners will be able to:<br><br>• Understand combustion kinetic pathways, chain reactions, and pollutant formation<br><br>• Describe common types of fuel cells, perform thermodynamic calculations based on conservation of energy for fuel cells | A5, MP5, Final [CLO6] |
| 12 | **Advanced technologies and the energy landscape** Reading: Lecture notes/slides<br>By the end of this week, learners will be able to:<br><br>• Critically assess new technologies and their potential for impact<br>• Quantify the environmental impact of leading energy technologies<br>• Understand the energy policy landscape | **Final exam** |

# COURSE COMMUNICATION

## QUESTIONS ABOUT COURSE MATERIAL

Questions or comments regarding the course material that can be of benefit to other students should be posted in the Q&A forum on the class website. The instructor, TAs, and students are encouraged to answer these questions directly in the discussion forum for the benefit of everyone in the course.

## 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 onQ course site.

## OFFICE HOURS

In addition to interaction in the Q&A discussion forums, you will have the opportunity to interact 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 48 hours.

## ABSENCES (ACADEMIC CONSIDERATIONS)

For information on academic considerations due to extenuating circumstances, please review the information on the FEAS website. Note that unacceptable reasons include extra-curricular activities, travel plans, generally behind on schoolwork, etc. Do not schedule travel during midterms and final exams, as travel is not an acceptable reason for granting academic considerations. For each category (traditional assignments and mini-projects), the lowest assignment grade will be dropped. In exceptional extenuating circumstances, the marks for additional missed assignments will redistributed. A missed midterm from an extenuating circumstance will lead to the marks from the midterm being added to the final exam or a rescheduled midterm.

## LATE POLICY

In the event of extenuating circumstances, you must follow the policies for requesting an academic consideration (as described above). In the absence of an approved consideration request, the normal late penalty will apply as described in the assignment or any course/departmental policies.

# STANDARD QUEEN'S AND SMITH ENGINEERING POLICIES

## 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.

## STUDENT CODE OF CONDUCT

Queen's University values maintaining an environment free of, and will not tolerate, harassment, discrimination, and reprisal. The Student Code of Conduct applies to all students at Queen's. It outlines the activities and behaviours that could be considered Non-Academic Misconduct (NAM). The Code also describes the NAM process and the sanctions that could be imposed on a student found responsible for a violation.
All students should be familiar with the Student code of conduct and related policies on sexual violence prevention and response and harassment and discrimination prevention and response.
https://www.queensu.ca/nonacademicmisconduct/policies

## 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 Smith Engineering 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.

## GENERATIVE ARTIFICIAL INTELLIGENCE (AI) TOOLS, LIKE CHATGPT

Using generative AI writing tools such as ChatGPT in your submitted work is prohibited in this class. This type of use constitutes a Departure from Academic Integrity.

## 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.

# 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 Smith Engineering Current Students web portal for information about various other policies such as

academic advisors, registration, student exchanges, awards and scholarships, etc. Students are also encouraged to review the information that is available in the EngQ Hub, posted in onQ.

## Absences (Academic Considerations) and Academic Accommodations

For academic accommodations and considerations please review the information on the Smith Engineering website.

## Accommodations for Disabilities

Queen's University is committed to working with students with disabilities to remove barriers to their academic goals. Queen's Student Accessibility Services (QSAS), students with disabilities, instructors, and faculty staff work together to provide and implement academic accommodations designed to allow students with disabilities equitable access to all course material (including in-class as well as exams). If you are a student currently experiencing barriers to your academics due to disability related reasons, and you would like to understand whether academic accommodations could support the removal of those barriers, please visit the QSAS website (https://www.queensu.ca/studentwellness/accessibility-services) to learn more about academic accommodations. To start the registration process with QSAS, click the ***Access Ventus*** button found on the Ventus student portal: https://www.queensu.ca/studentwellness/accessibility-services/ventus

Ventus is an online portal that connects students, instructors, Queen's Student Accessibility Services, the Exam's Office, and other support services in the process to request, assess, and implement academic accommodations. To learn more about Ventus, visit A Visual Guide to Ventus for Students: https://www.queensu.ca/ventus-support/students/visual-guide-ventus-students

For questions or assistance with requesting Academic Consideration or Accommodation, contact the Smith Engineering Program Advisor (Accommodations and Considerations) 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 | 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 discuss with your instructor how you can obtain an accommodation.

## 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 Chaplain@queensu.ca.

## Other human-rights based accessibility needs

Students who have accessibility needs based on human-rights covered grounds, should inform their instructors within a week of receiving their syllabus. Student can also contact the contact the Smith Engineering Program Advisor (Accommodations and Considerations) at engineering.aac@queensu.ca for guidance.

## 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 personal counselling and wellness services offered by Smith Engineering and the Queen's student wellness services.