Sample Syllabus **ME 404 Gas Turbines**
Fall 2024

Instructor: Dr. Jacqueline O'Connor
Professor of Mechanical Engineering
E-mail jxo22@psu.edu
Office: 111 Research East Phone: 814.863.1502
The best way to get me outside office hours is by e-mail – jxo22@psu.edu. Please do not use Canvas email – I will respond much more promptly if you use my PSU email account.

Class: MWF 10:10 – 11:00 AM, 167 Willard

Course book (recommended, not required): *Gas Turbine Theory*, 7th edition, Saravanamuttoo et al.

Office Hours: TBD

COURSE DESCRIPTION:
This course enables students with the proper background to gain specialized knowledge as a step towards becoming practitioners in the field of gas turbines. The information imparted covers from basic cycles to component design required to put together these impressive machines. The course will cover both the fundamentals as well as current topics in gas turbine design and operation for both power generation and aviation applications.

This course was completely redesigned in Fall 2020 due to the COVID-19 pandemic and several of the "lessons learned" are being applied in the current offering. This course has been designed in a somewhat "flipped" mode. Flipped courses include both asynchronous materials (labeled "pre-record" in the course schedule) as well as synchronous material. *This does not mean there is more material than a regular class!!* This just means, as you'll see below, that I'll be available to help with homework and do more examples (which I would normally put on video) during scheduled class times. The pre-record material is presented in short (5-15 minute) videos that should be watched *ahead* of the assigned date (see far-right column of the schedule). These videos provide basic material upon which we will build in class and will provide students with helpful and accessible material, as the textbook is *not* that helpful, unfortunately. The synchronous class times come in three flavors:

- Discussions of design, performance, and the industry (typically Mondays): these classes will provide context for the technical material we're learning. Bring your questions – I would love for these sessions to be highly interactive!
- Examples (typically Wednesdays): these classes will use data from real engines to apply the fundamentals (from the pre-records) in examples. Examples will be posted ahead of time so that students can follow along with the analysis.
- Team check-ins (typically Fridays): the homework will be done in teams in this course and on team check-in days, we'll meet in break-out sessions where we can discuss progress of the homework and I can help with any issues. This won't take the place of office hours – those still exist – but are a way to ensure that the team stays on track as these homework assignments will be involved.

The course ends with four weeks of case studies, the topics for which have not been established – I will be looking to the class to help me identify topics of interest. The typical class structure will change for these weeks depending on the case study topic.

LEARNING OBJECTIVES:
There are three types of learning outcomes I hope students achieve during this course: knowledge outcomes, skills outcomes, and perspective outcomes. As this is a senior-level technical elective, the outcomes of this class go beyond imparting basic knowledge to students, although that is certainly an important part of the course. I want students to develop critical skills as well as new perspectives over the course of the semester that you'll carry to other parts of your engineering career. This page describes those outcomes, which will be linked to different assignments throughout the semester.

<u>Knowledge Outcomes</u>
Knowledge Outcomes are outcomes related to basic knowledge about gas turbines, their operation, and their performance.

1. **Gas turbine components:** Students should be able to name all components of a gas turbine and describe the purpose and basic operational principles.
2. **Cycle analysis:** Students should be able to analyze a Brayton cycle, ideal and non-ideal, for different gas turbine architectures. This includes calculating how work, heat, and efficiency vary as a function of different operational parameters, like compressor pressure ratio, heat rate, component efficiencies, etc.
3. **Turbomachinery analysis:** Students should be able to use the Euler Turbomachinery Equation to connect the aerodynamic design of a stage of turbomachinery to its performance. Additionally, they should be able to use the equation to design a stage of turbomachinery based on desired performance.
4. **Combustor analysis:** Students will be able to calculate the heat added to a gas turbine cycle in the combustor in multiple ways for a range of fuels.

Skills Outcomes

Skills Outcomes are outcomes that transcend the study of gas turbines and can be applied to the analysis of a range of engineering problems.

1. **Identifying assumptions:** Solving for either component or cycle performance requires making some assumptions. This outcome ensures that students will be able to identify reasonable assumptions based on the level of accuracy that is appropriate for a given problem.
2. **Using published information for "back-out" analysis:** This skill is critical for all engineers - the ability to use publicly available but often incomplete data to "back-out" an answer in a calculation. For example, gas turbine companies will often quote compressor pressure ratio, net power, and engine exit temperature, but never combustor exit temperature; however, you can use the two pieces of information provided to estimate the combustor exit temperature using the information provided and some assumptions. This process of using a combination of incomplete information and assumptions is critical in all engineering analysis and will be developed in a number of ways in this course.
3. **Cycle modeling in Matlab:** Thermodynamic processes and cycles are found in a large range of engineering applications. In this skill, students will learn how to take fundamental conservation equations and apply them in Matlab (or other programming languages). In this way, students can vary parameters and inputs to plot trends and develop a fuller picture of system performance.

Perspective Outcomes

Perspective Outcomes are outcomes where students develop an appreciation for different perspectives on an engineering problem. For example, a solution could be optimized to meet economic goals, or regulation goals, or safety goals, or some combination of all of these. These new perspectives will add a new dimension to the students' analysis of engineering problems beyond the fundamental technical analyses that are presented in required core courses.

1. **Regulation perspective:** Regulation, whether it be for safety, emissions, performance, or cost, is a major part of the gas turbine industry. Designs must satisfy regulatory constraints, and we will discuss regulatory design drivers for a range of gas turbine technologies.
2. **Economics perspective:** The gas turbine industry is a for-profit industry and serves both regulated (electricity) and non-regulated (airlines) markets. In both cases, economic considerations play into the design and operation of these machines; this perspective will be covered throughout the course.
3. **Ethics perspective:** Beyond complying with regulation, engineers must also consider ethics in the work they do. We will discuss gas turbine design and operation in the context of engineering ethics.

TYPES OF ASSIGNMENTS

- **Homework:** homework is to be done in teams, which will be assigned at the beginning of the semester. Homeworks will typically include one large analysis, which will require Matlab to solve, and some discussion of the results from that analysis. If you are not comfortable with Matlab, there will be tutorial videos posted on Canvas for each homework; please also become familiar with the Matlab help file (https://www.mathworks.com/help/matlab/). Copying code from another group in the class is considered a violation of academic integrity.

- **Essays:** this class includes five essays, which are intended to help students practice discussing complex material in written form. There will be specific prompts and rubrics for each essay, and readings will be provided ahead of Essays 2-5. These essays will be graded both for content and presentation.

- **Quizzes:** quizzes will be online in Canvas and are *individual efforts*. These are short open-book, open-note check-ins on the material covered in each module to ensure that the student understands the basics. Practice problems will be provided ahead of the quizzes. They can be completed on the student's own time and are due at 11:59 PM on the days indicated in the schedule.

- **Final project:** the final project is an individual effort that focuses on an analysis of the student's choosing. More details of the project will be provided during the semester.

GRADING:

Homework:	40%
Class participation:	5%
Essays:	15%
Quizzes:	18%
Final Project:	22%
Late drops prior to first exam	-WN
Late drops after first exam:	
With a score ≥ 60%	-WP
With a score < 60%	-WF

GRADING	**SCALE**
A	93
A-	90
B+	87
B	83
B-	80
C+	77
C	70
D	60

CONTESTING GRADES: We are all human, and there may be grading mistakes from time to time. If you have an issue with how an assignment was graded, please provide a formal application for grade change, including a copy of the particular question and your original answer, and a paragraph explaining why you believe you deserve a grade change. These applications should be emailed to me NO EARLIER than 24 HOURS after the assignment was returned; verbal requests for grade change will not be considered. If there was an obvious mistake in grading, I will immediately correct the issue. If the grade change is more subjective in nature, I will file your request and reconsider at the end of the semester if a change in this grade could change your final grade in the class.

MISSED QUIZZES: No make-up quizzes will be given except as required by University policy. See me ***prior*** to any anticipated absence, preferably at the beginning of the semester.

COUNSELING AND PSYCHOLOGICAL SERVICES: Many students at Penn State face personal challenges or have psychological needs that may interfere with their academic progress, social development, or emotional wellbeing. The university offers a variety of confidential services to help you through difficult times, including individual and group counseling, crisis intervention, consultations, online chats, and mental health screenings. These services are provided by staff who welcome all students and embrace a philosophy respectful of clients' cultural and religious backgrounds, and sensitive to differences in race, ability, gender identity and sexual orientation.

- Counseling and Psychological Services at University Park (CAPS) (http://studentaffairs.psu.edu/counseling/): 814-863-0395
- Counseling and Psychological Services at Commonwealth Campuses (http://senate.psu.edu/faculty/counseling-services-at-commonwealth-campuses/)

- Penn State Crisis Line (24 hours/7 days/week): 877-229-6400
  Crisis Text Line (24 hours/7 days/week): Text LIONS to 741741

EDUCATIONAL EQUITY AND REPORTING BIAS: Consistent with University Policy AD29, students who believe they have experienced or observed a hate crime, an act of intolerance, discrimination, or harassment that occurs at Penn State are urged to report these incidents as outlined on the University's Report Bias webpage (http://equity.psu.edu/reportbias/)

STATEMENT ON ACCOMODATIONS FOR STUDENTS WITH DISABILITIES: Penn State welcomes students with disabilities into the University's educational programs. Every Penn State campus has an office for students with disabilities. The Student Disability Resources (SDR) website provides contact information for every Penn State campus: http://equity.psu.edu/sdr/campus-contacts. For further information, please visit Student Disability Resources: http://equity.psu.edu/sdr. In order to receive consideration for reasonable accommodations, you must contact the appropriate disability services office at the campus where you are officially enrolled, participate in an intake interview, and provide documentation: http://equity.psu.edu/sdr/guidelines. If the documentation supports your request for reasonable accommodations, your campus's disability services office will provide you with an accommodation letter. Please share this letter with your instructors and discuss the accommodations with them as early in your courses as possible. You must follow this process for every semester that you request accommodations.

STATEMENT ON ACADEMIC INTEGRITY: Academic dishonesty will not be tolerated ***at all***. I hope that everyone can develop enough pride in his or her own work and abilities that this will never be a problem. When you earn an Engineering degree from Penn State, the University is certifying that you are capable of performing engineering duties at a professional level. Course grades are the sole basis on which the College of Engineering certifies your degree with the assumption that your course grades are a valid assessment of your own knowledge and abilities. If you have cheated, you have falsified that credential. Therefore, we must have academic integrity expectations to ensure the validity of your grade and your degree. Detailed information on this topic can be found at https://www.engr.psu.edu/faculty-staff/academic-integrity.aspx. Some examples are given below:

CHEATING: Using crib sheet; pre-programming a calculator; using notes or books during a closed book exam etc.
COPYING ON TEST: Looking at another unsuspecting student's exam and copying; copying in a complicit manner with another student; exchanging color-coded exams for the purpose of copying; passing answers via notes; discussing answers in exam, etc.
PLAGIARISM: The fabrication of information and citations; submitting others work from professional journals, books, articles and papers; submission of other students papers or lab results or project reports and representing the work as one's own; fabricating in part or total, submissions and citing them falsely, etc.
ACTS OF AIDING OR ABEADING: Facilitating acts by others; unauthorized collaboration of work; permitting another to copy from exam; writing a paper for another; inappropriately collaborating on home assignment or exam without permission or when prohibited, etc.
UNAUTHORIZED POSSESSION: Of examinations, through purchase or supply; stealing exams; failing to return exams on file; selling exams; photocopying exams; buying exams; any possession of an exam without the custodian's permission, etc.
SUBMITTING PREVIOUS WORK: Submitting a paper, case study, lab report or any assignment that had been submitted for credit in a prior class without the knowledge and permission of the instructor.
TAMPERING WITH WORK: Changing own or another students work product such as lab results, papers, or test answers; tampering with work either as a prank or in order to sabotage another work, etc.
GHOSTING: Taking a quiz, an exam, performing a laboratory exercise or similar evaluation in place of another; having another take a quiz, an exam, or perform an exercise or similar evaluation in place of the student, etc.
ALTERING EXAMS: When instructor returns graded exams for in class review and subsequently collects them, student changes incorrect answers and seeks favorable grade adjustment asserting that instructor made mistake in grading; other forms may include changing the letter or and/numerical grade on test; obtaining test in discretely, etc.
COMPUTER THEFT PROGRAM: Electronic theft of computer programs, data, or text belonging to another etc.

Anticipated Class Lecture Schedule

Date	Topic	Reading
	Module 1: Course Introduction	
	Pre-record: Thermo Review 1-3	
	Pre-record: Fluids Review 1-2	
Week 1	Introduction and motivation	Saravanamuttoo 1.1-1.9
	Thermo/Fluids review problems	
	Review office hours	
	Module 2: Power Generation Design and Cycle Analysis	
	Pre-record: Power generation engine tour	
	Pre-record: Brayton cycle basics for power gen	Saravanamuttoo 2.1-2.5
Week 2	Power Generation Design Drivers and Performance	
	Gas Turbines on the Power Grid: Data Analysis	
	Team Check In: HW1	
Week 3	NO CLASS – LABOR DAY	
	Augmented Cycles	
	Augmented Cycles Analysis: Examples	
	Module 3: Aircraft Engines Design and Cycle Analysis	
	Pre-record: Aircraft engine tour	
	Pre-record: Introduction to propulsion	
	Pre-record: Stagnation quantities in aircraft engines	
	Pre-record: Aircraft engine cycle analysis	Saravanamuttoo 3.3-3.6
Week 4	Aircraft Engine Design Drivers, Performance Metrics	Saravanamuttoo 3.1
	Mission Planning Example	
	Team Check In: HW2	
Week 5	Turbojet Cycle Analysis Example	
	Turbofan Cycle Analysis Example	
	Team Check In: HW2	
	Module 4: Inlets and Exhausts	
	Pre-record: Passive device review and Ma effects	
	Pre-record: Inlet performance	
	Pre-record: Nozzle performance	
	Pre-record: Nozzle boundary conditions	
Week 6	Inlet/Exhaust Design Drivers	Saravanamuttoo 3.2
	Inlet/Exhaust Impacts on Cycle: Example	
	Team Check In: HW3	
	Module 5: Turbomachinery	
	Pre-record: Performance (ME300 review)	
	Pre-record: Basics of turbomachinery	Saravanamuttoo 5.1-5.2
	Pre-record: Euler turbomachinery equation	
	Pre-record: Connecting stage aero and thermo	
	Pre-record: Turbine velocity triangles	
Week 7	Turbomachinery Operability	Saravanamuttoo 5.12
	Introduction to Velocity Triangles	Saravanamuttoo 5.3
	Velocity Triangle Activity	

Week 8	Compressor Stability Guest Lecture	Saravanamuttoo 5.3-5.6, 5.11
	Multi-Stage Design	Saravanamuttoo 5.7
	Team Check In: HW4	
Week 9	Turbine vs. Compressor Design Drivers	Saravanamuttoo 7.1
	Component Matching Example	
	Team Check In: HW4	
Week 10	Turbine Heat Transfer Guest Lecture	Saravanamuttoo 7.6
	Module 6: Combustors	
	Pre-record (full length video): Lab tour	
	Pre-record: Combustable Mixtures	
	Pre-record: Energy conservation in reacting systems	Saravanamuttoo 6.5
	Introduction to Combustion	
	Team Check In: HW4	
Week 11	Combustor Design for Flame Stabilization	Saravanamuttoo 6.1-6.4
	Engine Combustion Example	
	Team Check In: HW5	
	Pre-record: Final project overview	
	Case Study 1:	
	Pre-record:	
	Pre-record:	
	Pre-record:	
Week 12		
	Team Check In: HW5	
	Case Study 2:	
	Pre-record:	
Week 13		
	Final project work session	
	THANKSGIVING BREAK	
	Case Study 3:	
	Pre-reading:	
Week 14		
	Final project work session	
	Case Study 4:	
	Pre-record:	
Week 15		
	Final project work session	
13-Dec	Final project due	

*Each of the homeworks will be due by the beginning of class or it is 15% off on the same day. Any day after the due date, but before solutions are posted is 50% off. After solutions are posted, the HW is counted as a zero.

SUBJECT TO CHANGE STATEMENT

Please note that this Course Syllabus is subject to change. Students are responsible for abiding by such changes.