Reacting Flows (MCEN6001/ASEN6519): Syllabus

Course Purpose: To establish a fundamental understanding of reacting flows and combustion.

Professor: Peter Hamlington Department of Mechanical Engineering
Office: ECME 222
Phone: (303) 492-0555
peter.hamlington@colorado.edu

Lectures: T/TH 9:30 – 10:45 AM in ECCR 135

Office Hours: T 11:00 AM – 1:00 PM, W 11:00 AM – 12:00 PM, all in ECME 222

Web Page: All relevant assignments, notes, slides, schedules, and supplemental documents will be posted to the course webpage at https://cuboulder.instructure.com/ throughout the semester. Please check the website to see what has been posted.

Required Text: *Principles of Combustion, 2nd Edition* by K.K. Kuo, Wiley & Sons, 2005.

Recommended Text: *An Introduction to Combustion: Concepts and Applications, 3rd Edition* by S.R. Turns, McGraw Hill, 2012.

Exam: There will be a final take-home exam. The exam will be emailed to the class on Friday, May 3 and will be due on Wednesday, May 9.

Topic outline: The material to be covered includes *(i)* a brief review of chemical thermodynamics, *(ii)* chemical kinetics and reaction mechanisms, *(iii)* conservation equations for single and multi-component reacting flows, including the fluid flow equations appropriate to reacting systems, *(iv)* detonation and deflagration waves, *(v)* premixed laminar flames, *(vi)* diffusion flames, and *(vii)* an introduction to turbulent reacting flows. These topics roughly correspond to Chapters 1-6 of the textbook by Kuo.

Prerequisites: Prior experience with fluid dynamics and thermodynamics is recommended. This course can be taken concurrently with another graduate fluid dynamics or thermodynamics course. We will approach the subject of reacting flows and combustion at a graduate mathematics level with extensive use of indicial notation, vector calculus, and differential calculus. Students with some prior experience with these topics will find the course easier to follow, since only a brief review of background material will be given.

Grading: Your final grade is determined according to the following percentage breakdown:

Homeworks…….20%
Project 1..……25%
Project 2……..30%
Final Exam……..25%

1. Course Notes and Policies

1.1 Reading assignments: Reading assignments are to be completed *before* the lecture/discussion. The lecture/discussions should help to clarify and supplement what you have read.

1.2 Homework: Homework assignments are due at the start of class on the due date. *There is a five-minute grace period, 9:30 am – 9:35 am, during which the homework may be submitted.* If you must miss class for an excused absence, you may submit your homework early. Late assignments are not accepted—that includes assignments slipped under the professor's door after class has started. However, if you will not be attending class you may submit your homework early by slipping it under the professor's door. If you know in advance that you must miss a homework due date, send your instructor an e-mail or voice mail to make arrangements.

Collaboration is permitted on homework. This means you may discuss the means and methods for solving problems and even compare answers, but you are not free to copy someone's assignment. The work that you turn in must be your own—copying is not allowed for any assignments.

It is your responsibility to make your homework solutions clear and legible. The graders have the discretion to deduct points for solutions that are hard to read or unprofessional in appearance. Unless the problem requires only a conceptual or short answer, the following format is recommended. This will facilitate grading and will assist you to approach problems in a consistent, organized way that will lead to the correct solution. Problems may be written by hand or typed, but must be submitted in hard copy. Email/electronic submittals will not be accepted.

i. Clear and succinct problem statement, including variables that are given and quantities to be found. This should be paraphrased and in your own words.
ii. Schematic/sketch (unless it is obviously not needed). Show the system to be analyzed and list relevant information on the figure.
iii. List of assumptions.
iv. Physical laws/governing equations and label the equations.
v. Solution
    a. First do the math, *in symbolic form*. Obtain and present a simplified expression for the answer.
    b. If a numerical solution is required, then do the calculations, plugging in the numbers. Pay attention to a) units and b) significant figures. Show all work.
    c. Present the answer with a box around it.
vi. Verification. Check the answer against what common sense tells you. Do the units make sense? Do the results compare reasonably to a related known quantity?

1.3 Projects: There will be two projects in the course. Project 1 will be a review paper on a *classic* journal article relevant to reacting flows and combustion. Project 2 will involve an in-depth analysis of a reacting flow or combustion problem of your choice. Detailed descriptions and grading rubrics for both projects will be distributed in advance of the project due dates. All projects should be uploaded to a dropbox on learn.colorado.edu and will be checked for plagiarism.

1.4 Exams: There will be one take-home exam in the course. You are expected to work independently on the exam and collaboration, using another student's work as your own, or allowing another student to use your work as their own is academic misconduct and is not tolerated.

1.5 Grading Scale: This will be the final grading scale used for the course. *There is no curve.* You are not competing against your classmates, so help them out if you can! I reserve the right to lower the scale (i.e., make it easier), but I will not raise it.

A	90+
A-	87-89
B+	85-86
B	83-84
B-	80-82

C+	77-79
C	74-76
C-	70-73
D+	68-69
D	63-67
D-	60-62
F	59 or below

1.6 Policy on Privacy of Graded Work: Federal law requires that your grades be communicated to you privately. You will be assigned a unique, private ID number for this purpose. Put this number on all work that you hand in, instead of or in addition to your name. You can pick up your graded work filed under this number. Grades will be posted on CULearn as well, where the ID number will also be available. Graded assignments will be placed in the ME common filing cabinet.

1.7 Accommodation of Disabilities or Religious Commitments: If you qualify for accommodations because of a disability, please submit to your professor a letter from Disability Services in a timely manner (for exam accommodations provide your letter at least one week prior to the exam) so that your needs can be addressed. Disability Services determines accommodations based on documented disabilities. Contact Disability Services at 303-492-8671 or by e-mail at dsinfo@colorado.edu.

If you have a temporary medical condition or injury, see Temporary Injuries under Quick Links at Disability Services website (http://disabilityservices.colorado.edu/) and discuss your needs with your professor.

Campus policy regarding religious observances requires that faculty make every effort to deal reasonably and fairly with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance. In this class, please provide at least two weeks notice of occasions that conflict with course due dates, so that other arrangements can be made.
See full details at http://www.colorado.edu/policies/fac_relig.html

2. Departmental Notes and Policies

2.1 Overview: A primary objective of the Department of Mechanical Engineering is to prepare students for careers in the engineering profession. As professionals, engineers must meet high standards of technical competence and ethical behavior. According to the Accreditation Board of Engineering and Technology (ABET) code of ethics, engineers uphold and advance the integrity, honor and dignity of the engineering profession by:

i. Using their knowledge and skill for the enhancement of human welfare;
ii. Being honest and impartial, and serving with fidelity the public, their employers and clients;
iii. Striving to increase the competence and prestige of the engineering profession.

The Department of Mechanical Engineering (ME) believes that it is essential for each of you to learn the professional behavior that will prepare you for your career after college. Therefore, in each course you will be required to practice the professional behavior that will be expected by your future employers. This syllabus clearly outlines the departmental policy regarding academic integrity and academic climate. These policies will be upheld in each of your courses throughout the mechanical engineering curriculum. However, we also expect that this culture of professionalism will pervade all of your University of Colorado experiences.

2.2 Academic Integrity: You will be asked to complete individual homework assignments in this course. Though you may work in groups to discuss and solve problems, it is expected that you will abide by the University of Colorado at Boulder honor code at all times. Therefore, you may not plagiarize a problem set or allow another student to plagiarize your answers to a problem set. Examples of plagiarism include: copying from a solution manual, copying from Internet sites, copying from previous academic year homework sets, and copying directly from classmates. If you have any doubt that you are using sanctioned materials to assist with your homework solution, please ask your current instructor/professor.

On assignments that require you to use supplemental materials, it is also essential that you properly document the sources of information you use.

Any instances of dishonesty on homework or tests will result in a minimum sanction for your first violation of the honor code of a zero score and an entry in your departmental file. Additional sanctions will be imposed for subsequent violations. You may contest any accusation according to the campus honor code system.

2.3 Academic Climate – In-Class Expectations: It is our expectation that each of you will be respectful to your fellow classmates and instructors at all times. In an effort to create a professional atmosphere within the classroom, it is requested that you:

- Arrive to class on time
- Turn off your cell phone
- Limit use of your laptop computer to class purposes
- Put away newspapers and magazines
- Refrain from having disruptive conversations during class
- Remain for the whole class, or if you must leave early do so without disrupting others
- Display professional courtesy and respect in all interactions related to this class

Compliance with these expectations will assist us with the creation of a learning community and a high quality educational experience. The University of Colorado Classroom behavior policy will compliment the outlined classroom expectations. The University of Colorado Classroom Behavior policy is stated below.

2.4 Academic Climate – Out of Class Expectations: Though many of the above stated policies address academic climate within the classroom, these policies should also be upheld outside of the classroom. As a member of the CU community you are expected to consistently demonstrate integrity and honor through your everyday actions. Furthermore, faculty and staff members are very willing to assist with your academic and personal needs. However, multiple professional obligations make it necessary for us to schedule our availability. Suggestions specific to interactions with faculty and staff include:

- Respect posted office hours. Plan your weekly schedule to align with scheduled office hours
- Avoid disrupting ongoing meetings within faculty and staff offices. Please wait until the meeting concludes before seeking assistance. Respect faculty and staff policies regarding use of email and note that staff and faculty are not expected to respond to email outside of business hours. Send emails to faculty and staff using a professional format. Tips for a professional email include:
    - Always fill in the subject line with a topic that indicates the reason for your email to your reader.
    - Respectfully address the individual to whom you are sending the email (e.g., Dear Professor Smith).
    - Avoid email, chat room or text message abbreviations.
    - Be brief and polite.
    - Add a signature block with appropriate contact information.
    - Reply to emails with the previously sent message. This will allow your reader to quickly recall the questions and previous conversation.

2.5 Discrimination and Harassment: Discriminatory and harassing behavior will not be tolerated in the Department of Mechanical Engineering. A safe and inclusive environment will be created and maintained by the students and instructing faculty member. Students with concerns about discrimination or harassment actions should immediately contact the instructor, the Department Chair or their academic advisor, or contact the Office of Discrimination and Harassment (below).

Examples that may be considered harassment:

A teaching assistant or instructor asking a student for a date.
Displaying sexually explicit material in an academic setting (including laptop wallpaper).
Persisting in asking a classmate for a date after being turned down.

Using degrading terminology in referring to others, including peers.
The University of Colorado Discrimination and Harassment policy is stated below.

3. University Notes and Policies

3.1 University of Colorado at Boulder Honor Code Policy: All students of the University of Colorado at Boulder are responsible for knowing and adhering to the academic integrity policy of this institution. Violations of this policy may include: cheating, plagiarism, aid of academic dishonesty, fabrication, lying, bribery, and threatening behavior. All incidents of academic misconduct shall be reported to the Honor Code Council (honor@colorado.edu; 303-735-2273). Students who are found to be in violation of the academic integrity policy will be subject to both academic sanctions from the faculty member and non-academic sanctions (including but not limited to university probation, suspension, or expulsion). Other information on the Honor Code can be found at http://www.colorado.edu/policies/honor.html and at http://honorcode.colorado.edu

3.2 University of Colorado Classroom Behavior Policy: Students and faculty each have responsibility for maintaining an appropriate learning environment. Those who fail to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with differences of race, color, culture, religion, creed, politics, veteran's status, sexual orientation, gender, gender identity and gender expression, age, disability, and nationalities. Class rosters are provided to the instructor with the student's legal name. I will gladly honor your request to address you by an alternate name or gender pronoun. Please advise me of this preference early in the semester so that I may make appropriate changes to my records. See policies at http://www.colorado.edu/policies/classbehavior.html and at http://www.colorado.edu/studentaffairs/judicialaffairs/code.html#student_code

3.3 University of Colorado Discrimination and Harassment Policy: The University of Colorado Boulder (CU-Boulder) is committed to maintaining a positive learning, working, and living environment. The University of Colorado does not discriminate on the basis of race, color, national origin, sex, age, disability, creed, religion, sexual orientation, or veteran status in admission and access to, and treatment and employment in, its educational programs and activities. (Regent Law, Article 10, amended 11/8/2001). CU-Boulder will not tolerate acts of discrimination or harassment based upon Protected Classes or related retaliation against or by any employee or student. For purposes of this CU-Boulder policy, "Protected Classes" refers to race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, or veteran status. Individuals who believe they have been discriminated against should contact the Office of Discrimination and Harassment (ODH) at 303-492-2127 or the Office of Student Conduct (OSC) at 303-492-5550. Information about the ODH, the above referenced policies, and the campus resources available to assist individuals regarding discrimination or harassment can be obtained at http://hr.colorado.edu/dh/

4. Assignment Schedule

Thursday 1/25 – Homework 1 Assigned
Thursday 2/8 – Homework 2 Assigned, **Homework 1 Due**
Thursday 2/15 – Project 1 Assigned
Thursday 2/22 – **Homework 2 Due**
Thursday 3/8 – Homework 3 Assigned, **Project 1 Due**
Thursday 3/22 – Project 2 Assigned, Homework 4 Assigned, **Homework 3 Due**
Thursday 4/5 – Homework 5 Assigned, **Homework 4 Due**
Thursday 4/19 – **Homework 5 Due**
Friday 5/4 – Final Exam Assigned, **Project 2 Due**
Wednesday 5/9 – **Final Exam Due**

This schedule is subject to change depending on the interests and progress of the class.