University Of California, Berkeley
Department of Mechanical Engineering

ME 255: Advanced Combustion Processes (3 units)

Graduate Course

Syllabus

CATALOG DESCRIPTION

Fundamentals of combustion, flame structure, flame speed, flammability, ignition, stirred reaction, kinetics and nonequilibrium processes, pollutant formation. Application to engines, energy production, and fire safety.

COURSE PREREQUISITES

ME 40, ME 106, and ME 109 or their equivalents.

TEXTBOOK(S) AND/OR OTHER REQUIRED MATERIAL

Required text: S. McAllister, J.Y. Chen and A.C. Fernandez-Pello "Fundamentals of Combustion Processes", Springer, 2011.

COURSE OBJECTIVES

The course provides an introduction to the subject of combustion, covering a broad range of topics important to the fields of energy conversion, engines, pollution and fires. It consists of classroom lectures and laboratory demonstration. It treats the fundamental processes occurring in combustion systems and emphasizes on technological-problem solving skills. The laboratory demonstrations provide practical experience with real combustion systems. The course also uses computer programs to aid the students in the calculations and analysis, especially in thermodynamics and chemical kinetics.

DESIRED COURSE OUTCOMES

Upon completion of the course, students shall be able to:
Understand and calculate the stoichiometry, adiabatic flame temperature and heat of combustion of a fuel and oxidizer mixture. Understand the role of elementary and global reactions. Calculate reaction rates. Know how to use computer codes (e.g. Cantera) to solve combustion problems. Understand and calculate the ignition characteristics of a fuel and oxidizer mixture: flammability limits, self-ignition. Understand and calculate the structure and properties of a premixed flame: propagation speed, thickness, quenching distance, and minimum ignition energy. Understand and calculate the structure and properties of a diffusion flame: height, lift-off distance and blow-off limit. Understand the formation of pollutants from hydrocarbon combustion. Understand the operation of practical systems, specifically, furnaces and boilers, spark ignition and diesel internal combustion engines, and gas turbines.

TOPICS COVERED

Nature of combustion. Types and characteristics of fuels. Thermodynamics: Heat of reaction and adiabatic flame temperature. Chemical Kinetics: Chemistry of combustion. Elementary and global reactions. Premixed flames: Laminar flame propagation. Flame speed and flammability. Ignition, extinction and quenching.

Laboratory experiments with the ignition and propagation of premixed flames. Diffusion flames: Gaseous diffusion jets and flames flame heights. Turbulent flames. Environmental impacts: Pollutants and its generation paths. Laboratory experiments with a Droplet Combustion: Droplet sprays. Evaporation and burning of droplets. Real combustion systems: Gas-fired furnace, burners. Premixed charge engines. Diesel engines. Gas turbines. Alternative engines. About ten laboratory demonstrations covering: Computer-aided analysis with Cantera, bomb calorimeter, ignition of premixed mixtures, premixed flames propagation, flash and fire points, diffusion flames, Burke-Schumann flames, pool fires, internal combustion engine, spray combustion, gas turbine combustor.

CLASS/LABORATORY SCHEDULE

Three hours of lecture and one hour of demonstration lab per week.

CONTRIBUTION OF THE COURSE TO MEETING THE PROFESSIONAL COMPONENT

This course provides experience with real combustion systems (measurement devices, flames, engines, turbines) and hands on experience with computer-aided analysis of combustion problems including thermodynamics and chemical kinetics. This course is an elective course in the Mechanical Engineering Professional M.Eng Program.

ASSESSMENT OF STUDENT PROGRESS TOWARD COURSE OBJECTIVES

Homework/laboratory and class-participation 20%
mid-terms 40%
final exam 40%

Participation in class and discussion sessions is strongly encouraged.

REMARKS

This is a room-share course that will be taught concurrently with ME 140. ME 140 and ME 255 will share a common lecture, but project/homework assignments for graduate students in ME 255 will be different than those for undergraduate students in ME 140. Compared to the projects assigned to undergraduates, graduate students taking ME 255 will be given project assignments that require modeling of more complex combustion systems, and use of more sophisticated computational tools. Final exam questions for graduate students in ME 255 will be different than those for undergraduate students in ME 140. Students who have taken ME140 are not allowed to take ME255.

TOPICS COVERED/WEEKLY AGENDA (SAMPLE)

WEEK #	LECTURE TOPICS	LAB
1	**Introduction:** The nature of combustion. Fuels.	None
2	**Thermodynamics of Combustion:** Thermodynamics review. Heat of reaction and formation.	#1: Cantera primer and ignition delay
3	**Thermodynamics of Combustion:** Adiabatic flame temperature.	#2: Bomb calorimeter
4	**Chemical kinetics:** Chemistry of combustion.	#3: Ignition of premixed gases
5	**Conservation Laws:** Open and closed control systems. Mass, energy, and momentum.	#4: Cantera premixed flame
6	**Ignition:** Ignition, extinction and quenching of premixed	#5: Cleveland cup - flash

	flames.	point
7	**Premixed combustion:** Laminar flame propagation. Flame speed. Flammability Limits. Flame Quenching	#6: Premixed flame propagation
8	**Non-premixed combustion:** Gaseous diffusion jets and flames.	#7: Non-premixed flames
9	**Solid Fuel Combustion:** Condensed fuel ignition. Material Flammability	#8: Pool fires
10	**Droplet and Spray Combustion:** Droplet burning. Droplet sprays.	None
11	**Environmental Aspects of Combustion:** Emissions	#9: Spray combustion
12	**Premixed Charge Engines:** Spark-Ignition Engine Combustion. Chamber Design and alternative engines.	#10: Internal combustion engine
13	**Diesel Engines:** Operating parameters, Fuel injection. Combustor and chamber design.	#11: Gas turbine combustor
14	**Gas turbines:** Liquid and gaseous fuel operations. Flame and emission characteristics.	None

PERSON(S) WHO PREPARED THIS DESCRIPTION

Carlos Fernandez-Pello, J.Y. Chen February 3, 2014

ABBREVIATED TRANSCRIPT TITLE (19 SPACES MAXIMUM):
TIE CODE: LECS
GRADING: Letter
SEMESTER OFFERED: Fall and Spring
COURSES THAT WILL RESTRICT CREDIT: ME 140
INSTRUCTORS: Professors Chen and Fernandez-Pello
DURATION OF COURSE: 15 Weeks
EST. TOTAL NUMBER OF REQUIRED HRS OF STUDENT WORK PER WEEK: 11
IS COURSE REPEATABLE FOR CREDIT? No
CROSSLIST: None
ROOMSHARE: ME 140