جامعة الملك عبدالله
للعلوم والتقنية
King Abdullah University of
Science and Technology

# Course Syllabus: Combustion - ME 244

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| **Division** | Physical Science and Engineering Division |
| **Course Number** | ME 244 |
| **Course Title** | Combustion |
| **Academic Semester** | Spring |
| **Academic Year** | 2017/2018 |
| **Semester Start Date** | 01/28/2018 |
| **Semester End Date** | 05/24/2018 |
| **Class Schedule** (Days & Time) | 04:00 PM - 05:30 PM \| Sun Thu |

## Instructor(s)

| Name | Email | Phone | Office Location | Office Hours |
|---|---|---|---|---|
| Gaetano Magnotti | GAETANO.MAGNOTTI@KAUST.EDU.SA | +966128082874 | 4335, 5, Al-Kindi (bldg. 5) | Wednesday 8:30-9:30 AM<br>Sunday and Thursday 5:30-6:30 PM |

## Teaching Assistant(s)

| Name | Email |
|---|---|
| No Teaching Assistant | |

## Course Information

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| **Comprehensive Course Description** | Fundamentals of Combustion. Basic flame types. Brief review of thermodynamics. Reactand and product mixtures. Chemical equilibrium and adiabatic flame temperature. Transport phenomena. Fundamentals of chemical kinetics. Reaction mechanisms: The H2-O2 system, CO oxidation, methane combustion, NO formation. Analysis of reaction mechanisms. Chemical and thermal analysis of reacting systems: Constant pressure reactor, constant volume reactor, well stirred reactor and plug-flow reactor. Conservation equations in reacting flows. Laminar premixed flames. Laminar diffusion flames. Ignition process. Fundamentals of turbulent combustion. Turbulent premixed flames. Turbulent diffusion flames. |
| **Course Description from Program Guide** | Basic principles including chemical equilibrium, Arrhenius law, and Rankine-Hugoniot relations will be first discussed. Multi-component conservation equations with chemical reaction will be introduced. Various characteristics of premixed and diffusion flames will be studied which covers flame structure, flame stability, flame stabilization, flammability limit, quenching distance, and thermal explosion. Combustion phenomena in gas turbines, gasoline engines, diesel engines and power plants will be discussed. A matched asymptotic expansion technique will be introduced and applied in analyzing flame structures. |
| **Goals and Objectives** | Introduce the fundamental of combustion. The students will be able to write conservation equations in presence of reaction and correctly apply them to describe fundamental combustion processes. They will learn the fundamental of chemical kinetics, and apply those concepts to the analysis of reactors, laminar premixed and non-premixed flames. During the course, the students will also learn how to use CEA and Chemkin software to compute chemical equilibrium, and simulate laminar flames. |
| **Required Knowledge** | Thermodynamics, and basic knowledge of continuum mechanics or fluid mechanics. |
| **Reference Texts** | Textbook "Combustion" by Warnatz, Maas, and Dibble<br>Recommended additional text: "An Introduction to Combustion, Concepts and Applications" by Stephen R. Turns, published by McGraw-Hill |

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| **Method of evaluation** | **30.00**% - Midterm exam<br>**25.00**% - Homework /Assignments<br>**35.00**% - Final exam<br>**10.00**% - Attendance and Participation |
| **Nature of the assignments** | Homeworks will consist of multiple answer questions, problems to solve manually and others that will require the use of software (NASA CEA and Chemkin). Collaboration for the homeworks is allowed, but copying from each other is strictly prohibited. |
| **Course Policies** | Attendance and participation are important, and accounted for in the final grade. Absences should be avoided, and must be justified.<br>Homeworks must be returned in time. Late homeworks will be graded, but points will be detracted for each day of delay. |
| **Additional Information** | |

## Tentative Course Schedule

*(Time, topic/emphasis & resources)*

| Week | Lectures | Topic |
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| 1 | Sun 01/28/2018 | Introduction to Combustion. Fundamental Definitions and basic flame types. |
| 1 | Thu 02/01/2018 | Brief Review of Thermodynamics. |
| 2 | Sun 02/04/2018 | Standard Enthalpies of formation. Chemical Equilibrium. Determination of Equilibrium Composition in gases. Determination of adiabatic flame temperature. |
| 2 | Thu 02/08/2018 | Transport Phenomena. |
| 3 | Sun 02/11/2018 | Introduction to Chemical Kinetics. Global versus elementary reactions. Elementary reaction rates. Rates of reaction for multistep mechanisms. |
| 3 | Thu 02/15/2018 | Analysis of reaction mechanisms . Sensitivity analysis, Reaction flow analysis, eigenvalue analisys. Reduced Mechanisms. |
| 4 | Sun 02/18/2018 | The H2-O2 system. CO oxidation. Oxidation of hydrocarbons. |
| 4 | Thu 02/22/2018 | Methane combustion. Oxides of Nitrogen formation. |
| 5 | Sun 02/25/2018 | Introduction to Chemkin. |
| 5 | Thu 03/01/2018 | Contant-pressure reactor. Constant volume reactor. |
| 6 | Sun 03/04/2018 | Well stirred reactor. Plug-flow reactor. |
| 6 | Thu 03/08/2018 | Conservation of mass and momentum in reacting flows. |
| 7 | Sun 03/11/2018 | Conservation of energy in reacting flows. The concept of conserved scalar. |
| 7 | Thu 03/15/2018 | Laminar premixed flames. Zeldovich's analysis of flame propagation. Structure of CH4-air flame. |
| 8 | Sun 03/18/2018 | Flame velocity and flame thickness in laminar premixed flames. |
| 8 | Thu 03/22/2018 | Quenching, flammability and ignition in laminar premixed flames. Flame stabilization. |
| 9 | Sun 03/25/2018 | Review |
| 9 | Thu 03/29/2018 | Mid-Term exam |
| 10 | Sun 04/01/2018 | Laminar diffusion flames. Mixing in non-reacting jets. Jet-flame physical description. |
| 10 | Thu 04/05/2018 | Simplified model for laminar jet non-premixed flames. |
| 11 | Sun 04/08/2018 | Laminar diffusion jet flames:flame length for circular port and slot burners. Basics of soot formation and destruction. |
| 11 | Thu 04/12/2018 | Counterflow flames. |
| 12 | Sun 04/15/2018 | Flame stretch: Phenomenology |
| 12 | Thu 04/19/2018 | Flame stretch: analysis |
| 13 | Sun 04/22/2018 | Fundamentals of turbulent combustion. Definition of turbulence. Length scale in turbulent combustion. |
| 13 | Thu 04/26/2018 | RANS of turbulent reacting flows. Axissymmetric turbulent jets. |
| 14 | Sun 04/29/2018 | Turbulent premixed flames. Practical applications. Turbulent flame speed. |
| 14 | Thu 05/03/2018 | Structure of turbulent premixed flames. |
| 15 | Sun 05/06/2018 | Wrinkled laminar flame regime. Distributed Reaction regime. Flamelet model. |
| 15 | Thu 05/10/2018 | Flame stabilization. |
| 16 | Sun 05/13/2018 | Turbulent non-premixed jet flames. |
| 16 | Thu 05/17/2018 | Turbulent non-premixed jet flames. |
| 17 | Sun 05/20/2018 | Review |
| 17 | Thu 05/24/2018 | Final Exam |

**Note**

The instructor reserves the right to make changes to this syllabus as necessary.