# MAE 704 Fluid Dynamics of Combustion II Spring 2026

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| Section: 001, 601 | Instructor: Prof. Tarek Echekki |
| Time: MW 11:45 am – 1:00 pm | Office: 3234 EB III |
| Place: 136 Monteith Eng. Res. Center | Office Hours: Tuesdays 1-3 pm |

**Official Catalog Description:** Advanced theory of detonation and deflagration. Ignition criteria. Direct initiation of detonation including blast-wave theory. Transition from deflagration to detonation. Combustion wave structure and stability. Liquid droplet and solid particle combustion.
**Actual Description:** Advanced concepts in combustion related to homogeneous and heterogeneous phase combustion of relevance to research and applications. Topics include laminar and diffusion flame theories and computations, turbulent combustion, high-speed combustion, droplet and solid fuel combustion, experimental combustion and emerging research areas in combustion.
**Prerequisites:** MAE 504.

**Reference Material:**
1. Chung K. Law, Combustion Physics, First Ed., Cambridge University Press, 2006 (accessible as an e-book through the library site).
2. N. Peters, Turbulent Combustion, First Ed., Cambridge University Press, 2000 (accessible as an e-book through the library site).
3. T. Echekki & E. Mastorakos (Eds), Turbulent Combustion Modeling, Springer, 2011 (accessible as an e-book through the library site).
4. Kenneth K. Kuo & Ragini Acharya, Fundamentals of Turbulent and Multiphase Combustion Processes, Wiley, 2012 (accessible as an e-book through the library site).
5. Online Journals: Combustion and Flame, Combustion Science and Technology, Progress in Energy and Combustion Science (NC State has subscription to these journals) and Combustion Theory and Modeling (NC State does not have subscription to this journal).
6. Online resources: Combustion Energy Frontier Research Center Summer School (https://cefrc.princeton.edu/combustion-summer-school).

**Course Grade**:

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| Homework (Individual) | 20% |
| Mini-projects (Individual or Group) | 50% |
| Final Project (Individual or Group) | 30% |

The final grade will be based on the final average and determined as follows:

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| A- (90 to < 93) | A (93 to < 97) | A+ (97 and above) |
| B- (80 to < 83) | B (83 to < 87) | B+ (87 to < 90) |
| C- (70 to < 73) | C (73 to < 77) | C+ (77 to < 80) |
| D- (60 to < 63) | D (63 to < 67) | D+ (67 to < 70) |
| F < 60 | | |

**Course Objectives:**

This course introduces advanced concepts in combustion as related to modern applications and research in combustion through modern theories, modeling and visits to experimental facilities. Traditional material in typical advanced combustion courses (laminar and diffusion flames theories, turbulent combustion and heterogeneous combustion) will be augmented by the addition of special topics that introduce emerging areas of research in combustion. The student is expected to gain critical analysis skills of the topics studied.

**<u>Topics</u>**

**<u>Continuation of Fundamentals from MAE 504</u>**

1. Governing equations for combustion flows (gas phase)
   - Continuity, momentum, species, energy, auxiliary equations
   - Simplified forms of these equations
   - Averaging and filtering of the governing equations under turbulent conditions
2. Laminar diffusion flame theory
   - The Burke-Schumann diffusion flame theory
   - Jet diffusion flames
   - Opposed jet diffusion flames and detailed flame structure
   - Stretch effects
   - Flame quenching and extinction
3. Heterogeneous combustion and Multiphase Processes
   - Governing equations for multiphase
   - Droplet combustion
   - Solid fuel combustion
   - Sprays

**<u>Advanced Topics</u>**

4. Reactor models and reactor networks
5. High speed combustion
   - Physical characteristics
   - Detonation waves and their structure and calculations of detonation speeds
   - Complex detonation structures.
6. Turbulent Combustion
   - Turbulence and combustion - Qualitative theory
   - Turbulent premixed and non-premixed flames: Turbulent combustion diagrams, the concepts of the turbulent flame speed, turbulent flame brush, surface area and surface density, flame stabilization, Turbulent combustion modeling

**<u>Special Topics/Applications</u>**

1. *Machine learning in combustion*
2. Pressure gain combustion
3. Internal combustion engine technologies (reciprocating engines, gas turbine engines)
4. Nonintrusive combustion measurements
5. Flameless combustion
6. Emerging research areas in combustion