Engineering Tripos Part IIB, 4A13: Combustion and Engines, 2026-27

Module Leader

Prof N Swaminathan [1]

Lecturers

Prof N Swaminathan [1]

Lecturer

Prof E. Masorakos [2]

Lab Leader

Timing and Structure

Lent term. 16 lectures, including 2 examples classes. Assessment: 100% exam

Prerequisites

3A5, 3A6 useful but not compulsory

Aims

The aims of the course are to:

- Introduce students to fundamental combustion concepts, and their influence on internal combustion engine and gas turbine performance and emissions.
- Introduce students to the changes required to use low-carbon fuels in these engines.

Objectives

As specific objectives, by the end of the course students should be able to:

- Understand fundamental concepts in combustion
- Understand combustion issues particularly relvant to gas turbines
- Understand the performance and efficiency characteristics of IC engines
- Understand the formation and after treatment of pollutants in IC engines and gas turbines and trade-offs with performance; understand the changes associated with the switch to low-carbon fuels.

Content

Chemical thermodynamics and equilibrium (1L)

Conservation laws for multicomponent mixture, multispecies equilibrium and calculation method

Chemical kinetics (1L)

Principles of chemical kinetics – law of mass action, activation energy, order & degree of a reaction, hydrocarbon reaction chains?, pollutant formation ?multistep reactions, chemical explosion, chemistry reduction using steady state and partial equilibrium approximations

Applications of chemical kinetics: limit reators (1L)

Common approximations used in combustion & chemical engineering analyses – perfectly stirred reactor, plug flow reactor, thermal explosions, autoignition & spark ignition

Laminar premixed flames (1L)

Concepts and measurements,? conservation equations in one and multiple dimensions, characteristic time and space scales, Zeldovich number, solution for 1D flame, flame speed and its dependence on mixture composition, temperature and pressure

Laminar non-premixed flames (1L)

Mixture fraction concept and its physical significance, conserved scalar approach, state relationship, simple solution for diffusion flame, droplet evaporation & combustion as an example for diffusion flame

Pollution from combustion (1L)

Nature of pollutants emitted by combustion and their effects on environment & human health, features of pollution generation chemistry, typical techniques used for emission reduction

Turbulent combustion (1L)

A brief introduction to turbulent combustion, its importance, applications, and scientific methods used to study turbulent combustion

Fundamental concepts in internal combustion engines (1L)

Overview of energy use in transportation, evolution of internal combustion and reciprocating engines, basic concepts and definitions, ideal constant volume and constant pressure cycles, efficiency, turbocharging, and hybridisation

Spark ignition & compression ignition engines (2L)

Basic concepts and definitions, valve timing and volumetric efficiency, residual gases, intake and fuel injection systems, combustion in SI engines, knock and limits to combustion, compression ignition process parameters, combustion under autoignition, fuel injection timing, torque and emissions, principles of turbocharging and relevant physics, turbocharger matching

Hybridisation and future concepts (1L)

New developments in combustion engines. Low-carbon fuels. Hybrid powertrain concepts and designs (series, parallel), downsizing, turbocharging, electric powertrain efficiency and control concepts

Gas turbine combustion (2L)

Basic concepts, combustor aerodynamics, two-phase flows, thermoacoustics, NO*x* and soot trade-off, combustor architectures, hydrogen, ammonia, synthetic aviation fuels

Emissions and aftertreatment (2L)

Emissions from IC engines and gas turbines, post-combustion clean-up (three-way catalysts, selective catalytic reduction, particulate matter removal), methods of in-flame control of NO*x* and soot, air-fuel ratio control, exhaust gas recirculation, NO*x* from H2 and NH3 combustion

Booklists

Please refer to the Booklist for Part IIB Courses for references to this module, this can be found on the associated Moodle course.

Examination Guidelines

Please refer to Form & conduct of the examinations [3].

UK-SPEC

This syllabus contributes to the following areas of the UK-SPEC [4] standard:

Toggle display of UK-SPEC areas.

General Learning Outcomes

Graduates with the exemplifying qualifications, irrespective of registration category or qualification level, must satisfy the following criteria:

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