Engineering Tripos Part IA, 1P1: Thermofluid Mechanics, 2022-23

Course Leader

Dr N Atkins [1]

Lecturer

Dr N Atkins [1]

Lecturer

Prof C Hall [2]

Timing and Structure

Weeks 1-5 Lent term (Dr N Atkins), Weeks 6-8 Lent term and weeks 1-4 Easter term (Prof C Hall), 24 lectures, 2 lectures/week

Aims

The aims of the course are to:

- Introduce the basic language of fluid dynamics (lift, drag, pressure, streamlines etc.).
- Familiarise students with the scope and applications of thermodynamics.
- Introduce the control volume concept
- Teach the conservation of mass, momentum and energy, and the Second Law of Thermodynamics, both for systems and for control volumes.
- Show how velocity and pressure are related.
- Teach the properties and behaviour of substances, especially of ideal gases.
- Examine engineering applications, such as buoyancy, flow measurement, lift and drag forces, etc.
- Demonstrate the application of the basic principles of Thermodynamics to the analysis of simple cycles.

Objectives

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

- Understand the concepts of mass, momentum, heat, work, energy and entropy in Thermofluid Mechanics.
- Understand the basic principles of hydrostatics.
- Understand how to use manometers and other instruments/tehcniques for the investigation of fluid flows.
- Identify a thermofluid system or control volume and the flows of mass, momentum, heat and work that are associated with a given problem.
- Understand the origin of lift and drag
- Apply the First and Second Laws of Thermodynamics to a system
- Evaluate entropy changes for reversible and irreversible processes.
- Decide when Bernoulli's equation is applicable to a fluid flow and then apply it.
- Understand the behaviour of pure substances, the meaning of selected properties (p,v,s, T,u,h) and their use in analyses, and how to determine their values using thermodynamic tables and analytical expressions (e.g. pv = RT).
- Understand the use of the isentropic relations for perfect gases.

- Understand the fundamental relationships of fluid dynamics and apply them to engineering problems.
- Perform thermodynamic analyses for ideal cycles such as the Otto ("gasoline engine"), Diesel and Joule ("gas turbine") cycles.

Content

PART 1 – FLUID MECHANICS (Dr N Atkins)

Introduction to Thermofluid Mechanics (1.0L)

- The significance of Fluid Mechanics and Thermodynamics
- What is a fluid?
- Forces in fluids.
- Terminology of Fluid Dynamics.

Fluid Statics (Hydrostatics) (2.0L)

- Basic equations.
- Variation of pressure with depth.
- Manometers and barometers.
- Forces on submerged bodies.
- Buoyancy and Archimedes' principle.

Control volume approach (1.0L)

- Systems and control volumes.
- Conservation of mass in control volumes.

Steady momentum equation (2.0L)

- Newton's 2nd law applied to control volumes (steady flow momentum equation).
- Steady momentum equation in two dimensions.

Bernoulli's equation (2.0L)

- Derivation.
- Applications (Venturi, discharge, flow measurement).
- Open channel flows.

Curved Streamlines (1.0L)

- Coanda effect.
- Magnus effect.
- Circulation and lift.

Summary and examples (1.0L)

PART II – THERMODYNAMICS (1.0L) (Dr C Hall, Lectures 11 – 24)

Introduction and Fundamental Concepts (1L)

- What is Thermodynamics?
- The scope of Thermodynamics.
- Classical Thermodynamics versus Molecular Thermodynamics.
- Thermodynamic Systems, Properties and Thermodynamic State.
- Thermodynamic Equilibrium, The Two-property rule.

The First Law of Thermodynamics (1L)

- Work, Heat and Energy.

- General statement of the First Law for a closed system.
- Cyclic processes, adiabatic processes.

Property Relations and Ideal Gases (1L)

- Pure substances and phases.
- Definition of enthalpy (H), specific heat capacities.
- Ideal gas relations: perfect and semi-perfect gases.

Application of the 1st Law to Perfect Gases (1L)

- Isobaric, isochoric and isothermal processes.
- Adiabatic compression and expansion.
- Polytropic processes.

The Second Law of Thermodynamic (1.5L)

- Reversible and irreversible processes.
- The Kelvin-Planck and Clausius statements of the Second Law.
- Heat engines, refrigerators and heat pumps.
- Cycle efficiency and coefficient of performance.
- The Carnot cycle.

Temperature (0.5L)

- The Zeroth Law of Thermodynamics.
- Empirical temperature scales, the perfect gas temperature scale.
- Thermodynamic temperature. Temperature measurement.

Entropy (2L)

- Revision of 1st and 2nd Laws
- The Clausius Inequality.
- The definition of entropy (S)
- Entropy changes for reversible and irreversible processes.

Application and Interpretation of Entropy (1L)

- The “Tds” equations. Entropy of a perfect gas.
- Entropy changes of isolated systems: principle of maximum entropy.
- Molecular interpretation

Applications I: Reciprocating internal combustion engines (1L)

- Spark ignition and compression ignition engines.
- The Air-standard cycles: Otto and Diesel.
- Practical considerations.

Control volume analysis (1L)

- Mass conservation revisited.
- First Law applied to control volumes

Steady Flow Processes (1L)

- The steady flow energy equation (SFEE).

- Throttling processes; compressors and turbines

The Second Law for Control Volumes (1L)

- Entropy changes for flow processes.
- Steady reversible and irreversible flow.
- Isentropic flow.

The Applications II: Gas Turbines and Jet Engines (1L)

- The air-standard Joule cycle.
- The jet engine.

Booklists

Please refer to the Booklist for Part IA 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.

GT1

Develop transferable skills that will be of value in a wide range of situations. These are exemplified by the Qualifications and Curriculum Authority Higher Level Key Skills and include problem solving, communication, and working with others, as well as the effective use of general IT facilities and information retrieval skills. They also include planning self-learning and improving performance, as the foundation for lifelong learning/CPD.

IA1

Apply appropriate quantitative science and engineering tools to the analysis of problems.

IA3

Comprehend the broad picture and thus work with an appropriate level of detail.

KU1

Demonstrate knowledge and understanding of essential facts, concepts, theories and principles of their engineering discipline, and its underpinning science and mathematics.

KU2

Have an appreciation of the wider multidisciplinary engineering context and its underlying principles.

E1

Ability to use fundamental knowledge to investigate new and emerging technologies.

E2

Ability to extract data pertinent to an unfamiliar problem, and apply its solution using computer based engineering tools when appropriate.

E3

Ability to apply mathematical and computer based models for solving problems in engineering, and the ability to assess the limitations of particular cases.

E4

Understanding of and ability to apply a systems approach to engineering problems.

P1

A thorough understanding of current practice and its limitations and some appreciation of likely new developments.

P3

Understanding of contexts in which engineering knowledge can be applied (e.g. operations and management, technology, development, etc).

US1

A comprehensive understanding of the scientific principles of own specialisation and related disciplines.

US2

A comprehensive knowledge and understanding of mathematical and computer models relevant to the engineering discipline, and an appreciation of their limitations.

US3

An understanding of concepts from a range of areas including some outside engineering, and the ability to apply them effectively in engineering projects.

US4

An awareness of developing technologies related to own specialisation.

Last modified: 27/09/2022 15:16

Source URL (modified on 27-09-22): https://teaching22-23.eng.cam.ac.uk/content/engineering-tripos-part-ia-1p1-thermofluid-mechanics-2022-23

Links
[1] mailto:nra27@cam.ac.uk
[2] mailto:cah1003@cam.ac.uk
[3] https://teaching22-23.eng.cam.ac.uk/content/form-conduct-examinations
[4] https://teaching22-23.eng.cam.ac.uk/content/uk-spec