Engineering Tripos Part IA, 1P1: Thermofluid Mechanics, 2026-27

Course Leader

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Lecturer

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Lecturer

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Timing and Structure

Weeks 1-5 Lent term, Weeks 6-8 Lent term and weeks 1-4 Easter term, 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 I – THERMODYNAMICS (Dr. C. Clark, Lectures 1 – 14)

PART 2 – FLUID MECHANICS (Prof. M. Juniper, Lectures 15 – 24)

Lecture 1: The Language of Thermodynamics

- scope of thermodynamics;
- classical versus molecular views;
- systems, properties, state;
- the two-property rule;
- equilibrium;
- the Zeroth Law;
- temperature scales and measurement.

Lecture 2: Energy Accounting: The First Law

- Work, heat and energy;
- pdV, shaft and electrical work;
- the First Law for a closed system;
- adiabatic and cyclic processes.

Lecture 3: The Working Fluid: Ideal and Perfect Gases

- the ideal gas equation;
- the specific gas constant;
- enthalpy;
- specific heats, c_p, c_v, and gamma;
- perfect and semi-perfect gases;
- tables.

Lecture 4: Processes: The First Law at Work

- isobaric, isochoric and isothermal processes;
- adiabatic processes;
- the isentropic relations;
- polytropic processes.

Lecture 5: The Second Law I: Direction

- reversible and irreversible processes;
- the Kelvin-Planck and Clausius statements;
- heat engines;
- cycle efficiency.

Lecture 6: The Second Law II: The Best Possible Machine

- The Carnot cycle;
- Carnot's theorems;
- refrigerators and heat pumps;
- coefficient of performance;
- thermodynamic temperature;
- absolute zero.

Lecture 7: The Second Law III: The Clausius Inequality

- from Carnot to Clausius: two reservoirs, then any cycle;
- the Clausius Inequality;

- a property in the equality.

Lecture 8: The Second Law IV: Entropy

- entropy defined
- reversible and irreversible entropy changes;
- entropy generation.

Lecture 9: The Second Law V: The Design Tool

- The Tds equations;
- entropy of a perfect gas;
- the T-s diagram;
- the principle of maximum entropy;
- molecular interpretation.

Lecture 10: Control Volumes

- Mass conservation;
- steady and unsteady flows;
- flow work;
- the First Law for a control volume.

Lecture 11: Steady Flow: The SFEE

- the steady flow energy equation; stagnation properties;
- the pitot tube;
- throttling;
- compressors and turbines.

Lecture 12: The Second Law for Control Volumes

- entropy in flow processes;
- reversible and irreversible steady flow;
- the integral of vdp;
- isentropic flow.

Lecture 13: Applications I: Reciprocating Engines

- work ratio;
- the Stirling engine;
- spark-ignition (SI) and compression ignition (CI) engines;
- the four-stroke cycle;
- air-standard Otto and Diesel cycles.

Lecture 14: Applications II: Gas Turbines and Jet Engines

- the air-standard Joule cycle;
- the jet engine.

Topic 1: From Thermodynamics to Fluid Mechanics

- modelling fluids;

- control volumes;
- steady flow energy equation;
- incorporation of 2nd law into SFEE;
- incompressible reversible flow;
- when a flow can be considered incompressble;
- the meaning of pressure in an incompressible fluid;
- terminology of fluid mechanics.

Topic 2: Incompressible fluid mechanics

- definition of a streamline in a steady flow;
- Bernoulli's equation;
- the Froude number;
- neglecting gravitational potential energy;
- neglecting kinetic energy;
- hydrodsatics;
- manometers and barometers;
- forces on submerged bodies;
- buoyancy and Archimedes' principle;
- neglecting flow work.

Topic 3: The Steady Flow Momentum Equation (SFME) I

- 1D channel flow with a free surface;
- steady flow momentum equation (SFME);
- the 1A channel flow experiment;
- the hydraulic jump;
- analogy with compressible flow

Topic 4: The Steady Flow Momentum Equation (SFME) II

- reminder of key concepts from 1D;
- conservation of mass, momentum, and (optionally) energy;
- fire hose problem
- applications (Venturi, discharge, flow measurement)
- mixing
- volumetric flowrates
- forces on a fluid in steady flow

Topic 5: Streamline Curvature

- acceleration of a fluid element;
- integration of Euler to obtain Bernoulli;
- centripetal acceleration and pressure gradients;
- stagnation points
- flows from nozzles
- flow separation in steady flow

Topic 6: Unsteady Flows

- unsteady flows;
- quasi-steady flows;
- streaklines and pathlines
- turbulence

Topic 7: Summary, Examples, and Outline of 1B and 2A

- momentum transfer and heat transfer
- boundary layers

- boundary layer separation
- Coanda effect
- Magnus effect

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.

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