Engineering Tripos Part IIA, 3A5: Thermodynamics & Power Generation, 2026-27

Module Leader

Dr A White [1]

Lecturers

Prof A Wheeler and Dr A White

Lab Leader

Prof A Wheeler [2]

Timing and Structure

Michaelmas term. Thermodynamics 2 lectures/week, weeks 1-4 (Dr Alex White); Power Generation: 2 lectures/week, weeks 5-8 (Prof Andy Wheeler). 16 lectures.

Aims

The aims of the course are to:

- Introduce some new concepts in thermodynamics, especially relating to chemical thermodynamics
- Focus on electricity power generation and the underlying thermodynamic theory.
- Introduce some concepts in thermo-mechanical energy storage to support intermittent generation technologies.
- Cover topics including power generation by direct electrochemical conversion by fuel cells, gas turbines, Rankine and combined cycles.
- Introduce some advanced cycle concepts, hydrogen-fuelled power plant and discuss the possibility of carbon dioxide capture and storage.

Objectives

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

- Understand the principles of exergy analysis, be able to calculate the lost work terms of power cycle components.
- Know the importance of the Helmholtz and Gibbs functions, the uses of standard property changes in chemical reactions, and the idea of rational efficiency..
- Understand the principles of electrochemical energy conversion, be aware of different types of fuel cell technology, be able to calculate the Gibbs and Nernst potentials, and have a basic knowledge of fuel cell losses.
- Understand the principles of phase equilibrium, the role of the chemical potential, and the Clausius-Clapeyron equation.
- Understand equation of state theory including characteristic form, Maxwell's relations, ideal gases, ideal gas mixtures, imperfect gases, van der Waals form, and law of corresponding states.
- Understand chemical equilibrium theory and the use of the equilbrium constant, be able to perform calculations for gas mixtures with one or two independent reactions, and be able to apply van't Hoff's

equation.
- Appreciate the need for energy storage and apply exergetic analysis to some thermo-mechanical storage concepts.
- Understand the rôle of a range of thermodynamic cycles in electricity power generation and be conversant with likely future developments.
- Be able to evaluate the performance of gas turbine plants including reheat, intercooling and recuperation.
- Be able to evaluate the performance of Rankine power plants including reheat and feedheating.
- Be able to evaluate the performance of combined cycles.
- Understand the issues involved in the capture and storage of carbon dioxide.

Content

Introduction, Thermodynamics and Energy Storage (9L)

- Overview of current and future electricity power generation, and the associated carbon emissions.
- Thermodynamic availability, lost work and entropy production, exergy analysis, application to power cycles.
- Gibbs and Helmholtz functions, standard property changes in chemical reactions, overall and rational efficiencies, electrochemical conversion, fuel cells (theory and practice).
- Equilibrium criteria, phase equilibrium, chemical potential, Clapeyron equation, equations of state, ideal gas mixtures, imperfect gases, van der Waals equation.
- Gibbs equation, chemical equilibrium, chemical potential of ideal gas, equilibrium constant, gas phase reactions, van't Hoff equation.
- Role of energy storage, description and anaysis of some storage tehnologies.

Power Generation (7L)

- Gas turbines (GTs) with intercooling, reheat and recuperation.
- Hydrogen-fired GTs and hydrogen production.
- Rankine cycles with feed heating and reheat. Thermodynamic cycles for nuclear, biomass, solar and geothermal power and low-grade heat recovery.
- Combined cycles (CCs): gas-steam CCGTs and and other CCs, including those employing Organic Rankine Cycles (ORCs).
- Advanced cycles and carbon dioxide sequestration.

Examples papers

1. 1B revision, exergetic analysis, chemical exergy and fuel cells
2. Gibbs and Helmholtz functions, phase and chemical equilibrium, equations of state, energy storage.
3. Gas turbine plant, intercooling and recuperation.
4. Steam plant, reheat, feed heat, combined cycles and ORCs.

Coursework

Computer based cycle simulation

Learning objectives:

- To consolidate the concept of exergy covered in lectures, and to apply this to the analysis of power-generating gas turbine cycles.
- To study the methods by which the efficiency and specific work output of a simple gas turbine plant may be improved.
- To investigate trends in cycle performance with various design parameters.

Practical information:

- Sessions will be able to complete the coursework online starting from week 2.
- This activity doesn't involve preliminary work.

Full Technical Report:

Students will have the option to submit a Full Technical Report.

Booklists

Please refer to the Booklist for Part IIA 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.

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.

S3

Understanding of the requirement for engineering activities to promote sustainable development.

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.

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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Links
[1] mailto:ajw36@cam.ac.uk
[2] mailto:aw329@cam.ac.uk
[3] https://teaching26-27.eng.cam.ac.uk/content/form-conduct-examinations
[4] https://teaching26-27.eng.cam.ac.uk/content/uk-spec