UNICUSANO
ROME

Italian code: ING-IND/09 (old) – IIND-06/B (new) **Credits: 9**
Course: Hostpital Energy Systems
Main language of instruction: Italian
Other language of instruction: English

Head instructor
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Objectives

The course aims to provide students with a solid understanding of the operating principles related to combined heat and power production systems and certain mechanical systems used in hospital facilities. Specifically, the course focuses on analyzing the main features of refrigeration systems, thermal motor systems with gas turbines, cogeneration and trigeneration systems, and ventilation and air conditioning systems commonly used in hospital settings.

The associated e-tivities, which involve writing technical documents in Word (or alternative free software such as OpenOffice), are designed to develop the skills necessary for solving practical application problems related to these systems.

The course "Hospital Energy Systems" has the following educational objectives:

1. To review the fundamental principles of thermodynamics and illustrate their application in energy systems of interest.
2. To explain the operating principles of refrigeration machines and heat pumps.
3. To describe the operating principles of thermal motor systems with gas turbines.
4. To present the basic concepts and operating principles of cogeneration and trigeneration systems.
5. To outline the main features of ventilation and air conditioning systems used in hospital facilities.

Course structure

Module 01 – Applied Thermodynamics, Part 1
Module 02 – Applied Thermodynamics, Part 2
Module 03 – Refrigeration Machines and Heat Pumps
Module 04 – Thermal Power Plants with Gas Turbine
Module 05 – Cogeneration and Trigeneration
Module 06 – HVAC Systems
Module 07 – HVAC Systems in Hospital Facilities

Competencies

A. Knowledge and understanding:
The student will be capable of demonstrating knowledge of the fundamental concepts related to combined heat and power generation systems, as well as ventilation and air conditioning systems employed in hospital environments. The student will also develop analytical skills for these systems. Additionally, through the e-tivities, the student will gain the ability to formulate and solve practical problems related to the operation of these systems.
B. Applying knowledge and understanding:
The student will be able to apply basic thermodynamics concepts and the principles of machine operation for the technical analysis of energy conversion systems, with particular focus on systems commonly used in hospital facilities. The e-tivities will involve applying theoretical knowledge to practical problems. The student will acquire critical skills to interpret numerical results, assessing both the physical coherence of the outcomes and the engineering feasibility of the proposed solutions.
C. Making judgements:
The student will be capable of identifying the most appropriate problem-solving methods and mathematical formulations to describe and resolve the problems addressed, in alignment with the theoretical framework presented during lectures.
D. Communication skills:
The student will be capable of identifying the most appropriate problem-solving methods and mathematical formulations to describe and resolve the problems addressed, in alignment with the theoretical framework presented during lectures.
E. Learning skills:
The student will be capable of identifying the most appropriate problem-solving methods and mathematical formulations to describe and resolve the problems

addressed, in alignment with the theoretical framework presented during lectures.

Syllabus

Module 01 – Applied Thermodynamics, Part 1

- Fundamental concepts.
- Work for closed systems.
- Driving work.
- Work for open systems.
- The first law of thermodynamics.
- Energy analysis of steady-flow systems.
- Specific heats.
- Perfect gases.

Exercises for Module 01

Module 02 – Applied Thermodynamics, Part 2

- The second law of thermodynamics.
- Technical transformations of perfect gases.
- Compression of a perfect gas and counter-recovery phenomena.
- Expansion of a perfect gas and recovery phenomena.
- Liquid-vapor systems.

Exercises for Module 02

E-tivity 1 – Module 02

- Exercises on the basic concepts of thermodynamics, particularly the technical transformations of perfect gases.
- Students must submit a written report in electronic format to the instructor for evaluation.

E-tivity 2 – Module 02

- Exercises on liquid-vapor systems.
- Students must submit a written report in electronic format to the instructor for evaluation.

Module 03 – Refrigeration Machines and Heat Pumps

- General concepts.
- Coefficient of performance.
- Carnot reverse cycle.
- Single-stage vapor compression refrigeration cycles.
- Multi-stage vapor compression refrigeration cycles.
- Components of vapor compression refrigeration systems.
- Properties of refrigerants.
- Absorption systems.

Exercises for Module 03

E-tivity 3 – Module 03

- Exercise on the analysis of a dual-stage vapor compression refrigeration system.
- Students must submit a written report in electronic format to the instructor for evaluation.

Module 04 – Thermal Power Plants with Gas Turbines

- The basic circuit.
- Combustion process.
- Ideal cycle.
- Boundary cycle.
- Real cycle.
- Overall efficiency of a thermal power plant with a gas turbine.

Exercises for Module 04

Module 05 – Cogeneration and Trigeneration

- General principles.
- Energy balances.
- Performance indices.
- Analysis of different types of cogeneration and trigeneration plants.
- Cogeneration and trigeneration systems with gas turbines.
- Surface heat exchangers.
- Heat recovery steam generators.

Exercises for Module 05

Module 06 – HVAC Systems

- General considerations.
- Air-only ventilation and air conditioning systems:
  - Air handling units,
  - Single-duct, dual-duct, and multi-zone systems,
  - Constant and variable air volume systems.
- Mixed air-water ventilation and air conditioning systems:
  - Fan-coils,
  - Induction units,
  - Two-pipe, three-pipe, and four-pipe systems.

Module 07 – HVAC Systems in Hospital Facilities

- General concepts.
- Contamination control.
- Air distribution systems in environments: turbulent, laminar, and mixed flow systems.
- Technical solutions for ventilation and air conditioning systems in hospital facilities.

Evaluation system and criteria

The exam consists of one or two written tests (depending on the chosen exam format, as described below) lasting 90 minutes, aimed at assessing analytical and conceptual skills, as well as the activities (e-tivities) completed during the virtual classes.
The written tests and the e-tivities contribute to the evaluation of the expected learning outcomes regarding subject knowledge, the ability to apply this knowledge, communication skills, and the ability to draw conclusions.

Evaluation of E-tivities

E-tivities are evaluated during the course, contributing 0 to 3 points overall. They are optional but highly recommended.

Exam Format
The remaining 0 to 27 points are awarded for the written exam, which can be taken either in Rome or at the designated teaching centers, upon student registration. The exam can be completed as a single test or split into two parts:

INTEGRAL EXAM
This format includes 1 or 2 exercises and possibly 1 theoretical question, covering the entire syllabus. It is graded on a scale of 0 to 27 points.
PARTIAL EXAMS
This format divides the exam into two parts to be taken during different exam sessions, each focused on a specific portion of the syllabus:
Partial Exam 1 Covers Modules 1, 2, 3, and 4.
Includes 1 to 3 exercises/theoretical questions.
Graded on a scale of 0 to 12 points, with a minimum passing score of 6/12.
Scores for this exam remain valid for up to 6 months. If the second partial exam is not taken or the overall exam is not passed within this period, the grade for this exam will be invalidated.
Partial Exam 2 Covers Modules 5, 6, and 7.
Includes 1 to 3 exercises/theoretical questions.
Graded on a scale of 0 to 15 points.

During the exam, the student must specify the chosen exam format. If no preference or multiple options are indicated, the integral exam format will automatically be applied. Note that the second partial exam can only be taken after successfully completing the first. If a student attempts the second exam without passing the first, the attempt will be deemed invalid

Bibliography and resources

1. *Materials to consult*

Notes written by the instructor are available in Italian (part of the notes are also available in English).

2. *Recommended bibliography*

Suggested readings are:

Çengel, Yunus A. (2008). Thermodynamics : an engineering approach. Boston :McGraw-Hill Higher Education
Baum, M., Burpee, H., Crabb, J., & Vernon, W. (2024). Decarbonizing Hospital Buildings: ASHRAE Task Force for Building Decarbonization.
HVAC Design Manual for Hospitals and Clinics, 2nd ed. (2013). American Society of Heating, Refrigerating and Air-Conditioning Engineers.