Summary
This course provides an integrated approach to analyze indoor thermal comfort by examining thermodynamics of heat flows in buildings and correlation between indoor thermal environment, performance of the building envelope and thermal conditioning systems (HVAC).

Content
Energy, entropy and exergy concepts; their application to analyze technical services of buildings. Indoor thermal comfort and ventilation requirements, indoor environmental standards. Thermal conditioning, heat/cold generation and distribution systems, loads calculation. Exergy analysis of various systems used for thermal management and ventilation of buildings. Practical evaluation of indoor comfort, energy, and exergy of air conditioning in building prototype.

Keywords
Thermal comfort, thermal conditioning, HVAC, thermodynamics, energy efficiency, energy analysis.

Learning Prerequisites
Required courses
N/A

Recommended courses
- Thermodynamics and energetics (ME-251)
- Building energetics (ENG-445)
- Comfort and architecture: sustainable strategies (AR-442)

Important concepts to start the course
- Energy, entropy and exergy
- Indoor environmental quality (IEQ), thermal comfort requirements
- Thermal conditioning needs in buildings

Learning Outcomes
By the end of the course, the student must be able to:
• Characterize performance performance of the building envelope, know the basic principles of HVAC equipment and efficiency parameters, critically evaluate the dynamic performance of the ventilation and heating/cooling
• Use the concept of exergy as a measure to evaluate sustainability of heating/cooling services and ventilation in buildings
• Assess / Evaluate energy and exergy expenditure to provide indoor comfort
• Carry out measurements of indoor comfort and energy performance using diagnostic instrumentation
• Take into consideration energy performance and requirements of IEQ standards
• Perform data analysis and presentation
• Specify Indoor comfort requirements

Transversal skills
• Write a scientific or technical report.
• Demonstrate the capacity for critical thinking
• Make an oral presentation.
• Plan and carry out activities in a way which makes optimal use of available time and other resources.

Teaching methods
- Lectures and exercises for theoretical introduction to the search of the equilibrium between thermal comfort, performance of the building envelope and mechanical systems; comparative analysis of energy and exergy performance of thermal conditioning systems in buildings
- Laboratory activity to enrich understanding of students on indoor comfort and the associated energy expense. Students will perform measurements of the indoor thermal comfort in an office room and analyze exergy flow and energy consumption of the integrated HVAC system. The test facility is a small building prototype located on the smart living lab site in Fribourg

Expected student activities
Participate in lectures, work on exercises, work in groups on measurements in building prototype, analyze results and write a technical report

Assessment methods
Mid-term exam: 20%
Laboratory report: 50%
Final exam: 30%

Supervision
Office hours Yes
Assistants Yes
Forum No

Resources
Bibliography
• 2017 ASHRAE Hanbook – Fundamentals
• C.-E. Hagentoft, Introduction to Building Physics, Studenlitteratur, 2001
• M. Pinteri, Building Physics: from Physical Principles to International Standards, Springer, 2017
• P. O. Fanger, Thermal Comfort, Danish Technical Press, 1970

Ressources en bibliothèque
• C.-E. Hagentoft, Introduction to Building Physics, Studenlitteratur, 2001
• M. Pinteric, Building Physics: from Physical Principles to International Standards, Springer, 2017
• 2017 ASHRAE Hanbook - Fundamentals
• P. O. Fanger, Thermal Comfort, Danish Technical Press, 1970

Websites
• http://www.lowex.net
• http://www.annex69.org

Prerequisite for
Master Project