

Course “Urban Thermodynamics”

Responsible Instructors:

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Instruction Language: English

Semester: BA5

Credits: 3

Schedule: **Mondays**, classroom **INJ 218** (lectures 15:15-17:00, practice session 17:15-18:00)

SUMMARY:

Urban settlements are complex human-made systems where interaction between the outdoor environment, structures, and humans follow physical laws of thermodynamics. Therefore, this course introduces the analysis of urban neighborhoods from a thermodynamics perspective, considering the heat exchange between different urban elements such as buildings, vegetation, blue areas, ground, and the surrounding environment. The complex interaction of all urban factors is presented considering a case study neighborhood at EPFL. Special attention is paid to the Urban Heat Island effect and mitigation strategies. In addition, the direct and indirect effect of the outdoor environment on the comfort of humans is discussed.

CONTENT:

- Analysis of urban physical processes at various scales
- Features of the urban environment and urban micro-meteorology
- Thermal interactions among environment, buildings, vegetation, ground, and water surfaces
- Spatial distribution and dynamics of airflow, temperature, and humidity in urban areas
- Influence of materials and urban design on thermal heat exchange and the environmental quality
- Impact of urban elements on urban climate and outdoor comfort

KEYWORDS:

Urban heat exchange, built environment, urban heat island effect, outdoor environmental quality, climate-sensitive urban design

LEARNING OUTCOMES:

By the end of the course, the student must be able to:

- Evaluate various modes of heat transfer in the urban environment
- Assess surface energy balance at various urban interfaces
- Carry out thermodynamic analysis at the urban scale
- Critique the choice of urban materials and design and propose alternative solutions
- Examine the effect of the outdoor built environment on human comfort

ASSESSMENT METHOD:

Quiz (30%) + Group project (70%)

GROUP PROJECT:

Detailed description is provided in a separate file

REQUIRED TOOLS:

ENVI-met (see project description file how to access the tool)

SCHEDULE:**Lectures (L) 15:15-17:00, practice sessions (P) 17:15-18:00, room INJ218**

Week	Date	Time	ID	Topics	Responsible
1	09.09	2 x 45'	L1	Course overview (content, evaluation, group project). Urban characteristics, Urban Heat Island (UHI) effect.	DK
		1 x 45'	P1	Exercises based on materials in lecture L1	KL
2	16.09	No class (holiday)			
3	23.09	2 x 45'	L2	Overview of physical parameters. Urban environment and urban modeling.	DK, KL
		1 x 45'	P2	Workshop on how to use the simulation tool ENVI-met (basic functions, geometry input, etc.) Exercises based on materials in lecture L2 [HW]	KL
4	30.09	2 x 45'	L3	Heat Transfer: Conduction and radiation	DK
		1 x 45'	P3	Exercises based on materials in lecture L3	KL
5	07.10	2 x 45'	L4	Heat Transfer: Convection and evaporation	DK
		1 x 45'	P4	Exercises based on materials in lecture L4	KL
6	14.10	90'	Q	Quiz (open book exam, based on lectures L1-L4)	DK, KL
		1 x 45'	V	Case study site (EPFL Innovation park) visit, overview of important urban features	DK, KL
7	21.10	Fall Break (no classes)			
8	28.10	2 x 45'	L5	Building-environment interaction: thermal, aerodynamic, and hydrodynamic interaction	DK
		1 x 45'	P5	Group work—simulation practice based on L5: building-environment interactions, workflow to create and modify building geometry, and materials for building walls and roofs. Data visualization for building surface temperature and visualization for scenario comparison	KL
9	04.11	2 x 45'	L6	Ground-environment interaction: ground properties, thermal, aerodynamic, and hydrodynamic interaction	DK
		1 x 45'	P6	Group work – simulation practice based on L6: relevant parameters for ground materials, soil profile, and data analysis regarding ground-environment interactions	KL
10	11.11	2 x 45'	L7	Water body - environment interaction: thermal, aerodynamic, and hydrodynamic interaction	DK
		1 x 45'	P7	Group work – simulation practice based on L7: workflow to create different water bodies and fountains in ENVI-met and data analysis for water-environment interactions	KL
11	18.11	2 x 45'	L8	Vegetation – environment interaction: characteristics of vegetation, evapotranspiration, aero- and thermal interaction	KL
		1 x 45'	P8	Group work – simulation practice based on L8: two modes of vegetation models in ENVI-met and methods to create new vegetation profiles, green walls and roofs, data analysis for vegetation-environment interactions	KL

12	25.11	2 x 45'	L9	Human Outdoor Comfort: Parameters affecting human comfort and comfort indices (UTCI, PET)	DK
		1 x 45'	P9	Group work – simulation practice based on L9: methods to calculate thermal comfort indices from ENVI-met simulation, dynamic thermal comfort simulation	KL
13	02.12	3 x 45'	--	Intermediate presentations of group projects	DK, KL
14	09.12	2 x 45'	L10	Climate-Sensitive Urban Design: complex interaction of all urban elements and their effect on UHI and outdoor environmental quality	KL
		1 x 45'	P10	Group work – simulation practice based on L10: developing an integrated solution in ENVI-met for the climate-sensitive urban design	KL
15	16.12	2 x 45'	L11	Urban Energy (renewable energy sources in cities). Summary of the course.	DK
		1 x 45'	P11	Group work - finalizing the analysis and the report	KL
Submission of group projects and peer-evaluation by 23.12 (12:00)					

MAIN REFERENCES:

- T.R. Oke, G.Mills, A. Christensen, J.A. Vooght, **Urban Climates**, Cambridge University Press
➤ ebook (PDF file) is available [here](#), 3 printed copies are available in the library
- S. Medved, **Building Physics: Heat, Ventilation, Moisture, Light, Sound, Fire, and Urban Microclimate**, Springer
➤ ebook (PDF file) is available [here](#), 1 printed copy is available in the library
- A. Rodrigues, R.A. Sardinha, G. Pita, **Fundamental Principles of Environmental Physics**, Springer
➤ ebook (PDF file) is available [here](#), no printed copy is available in the library
- N. Mason, P. Hughes, **Introduction to Environmental Physics: Planet Earth, Life and Climate**, Taylor & Francis
➤ ebook (PDF file) is available [here](#), 1 printed copy is available in the library