



Hugo Hens

# Building Physics Heat, Air and Moisture

Fundamentals and Engineering  
Methods with Examples and  
Exercises

2nd Edition



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*To my wife, children and grandchildren*

*In remembrance of Professor A. De Grave  
who introduced Building Physics as a new discipline  
at the University of Leuven (KU Leuven), Belgium in 1952*

This second edition represents a complete revision of the first edition, published in 2007. Where appropriate, the text was corrected, reworked, and extended. The exercises have been reviewed and solutions for all 33 problems added.

# Preface

## Overview

Until the first energy crisis of 1973, building physics was a rather dormant field in building engineering, with seemingly limited applicability. While soil mechanics, structural mechanics, building materials, building construction and HVAC were seen as essential, designers only demanded advice on room acoustics, moisture tolerance, summer comfort or lighting when really needed or problems arose. Energy was not even a concern, while thermal comfort and indoor environmental quality were presumably guaranteed thanks to infiltration, window operation and the HVAC system. The crises of the 1970s, persisting moisture problems, complaints about sick buildings, thermal, visual and olfactory discomfort, and the move towards more sustainability changed all that. The societal pressure to diminish energy consumptions in buildings without degrading usability opened the door for the notion of performance based design and construction. As a result, building physics and its potentiality to quantify performances suddenly moved into the frontline of building innovation.

As with all engineering sciences, building physics is oriented towards application. This demands a sound knowledge of the basics in each of the branches encompassed: heat and mass transfer, acoustics, lighting, energy and indoor environmental quality. Integrating the basics on heat and mass transfer is the main objective of this book, with mass limited to air, water vapour and moisture. It is the result of thirty years of teaching architectural, building and civil engineers, and forty-four years of experience, research and consultancy. Input and literature from over the world has been used, documented after each chapter by an extended literature list.

An introductory chapter presents building physics as a discipline. The first part concentrates on heat transport, with conduction, convection and radiation as main topics, followed by concepts and applications which are typical for building physics. The second part treats mass transport, with air, water vapour and moisture as the most important components. Again, much attention is devoted to the concepts and applications which relate to buildings. The last part discusses combines heat, air, moisture transport, who act as a trio. The three parts are followed by exemplary exercises.

The book is written in SI-units. It should be usable for undergraduate and graduate studies in architectural and building engineering, although also mechanical engineers studying HVAC, and practising building engineers who want to refresh their knowledge, may benefit. The level of presentation presumes the reader has a sound knowledge of calculus and differential equations along with a background in physics, thermodynamics, hydraulics, building materials and building construction.

## Acknowledgements

A book of this magnitude reflects the work of many persons in addition to the author. Therefore, we would like to thank the thousands of students we had during the thirty years of teaching building physics. They provided the opportunity to test the content. It is a book which would not have been written the way it is, without standing on the shoulders of those in the field who preceded. Although I started my career as a structural engineer, my predecessor, Professor Antoine de Grave, planted the seeds that fed my interest in building physics. The late Bob Vos of TNO, the Netherlands, and Helmut Künzel of the Fraunhofer Institut für Bauphysik, Germany, showed me the importance of experimental work and field testing for understand-

ing building performance, while Lars Erik Nevander of Lund University, Sweden, taught that complex modelling does not always help in solving problems in building physics, mainly because reality in building construction is much more complex than any model may be.

During four decades at the Laboratory of Building Physics, many researchers and Ph. D.-students got involved in the project. I am very grateful to Gerrit Vermeir, Staf Roels Dirk Saelens and Hans Janssen who became colleagues at the university; to Jan Carmeliet, now professor at the ETH-Zürich; Piet Standaert, a principal at Physibel Engineering; Jan Lecompte, at Bekaert NV; Filip Descamps, a principal at Daidalos Engineering and part-time professor at the Free University Brussels (VUB); Arnold Janssens, associate professor at the University of Ghent (UG); Rongjin Zheng, associate professor at Zhejiang University, China, and Bert Blocken, professor at the Technical University Eindhoven (TU/e), who all contributed by their work. The experiences gained by working as a structural engineer and building site supervisor at the start of my career, as building assessor over the years, as researcher and operating agent of four Annexes of the IEA, and Executive Committee on Energy Conservation in Buildings and Community Systems forced me to rethink the engineering based performance approach time and time again. The idea exchange we got in Canada and the USA from Kumar Kumaran, Paul Fazio, Bill Brown, William B. Rose, Joe Lstiburek and Anton Ten Wolde was also of great help. A number of reviewers took time to examine the first edition of this book. We would like to thank them, too.

Finally, I thank my wife Lieve who managed living with a busy engineering professor, and my three children who also had to live with that busy father, not to mention my many grandchildren who do not know their grandfather is still busy.

*Leuven, March 2012*

*Hugo S. L. C. Hens*

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