Simulating Experiments using a Comsol Application for Teaching Scientific Research Methods

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COMSOL CONFERENCE 2015 GRENOBLE

TU/e Technische Universiteit Eindhoven University of Technology

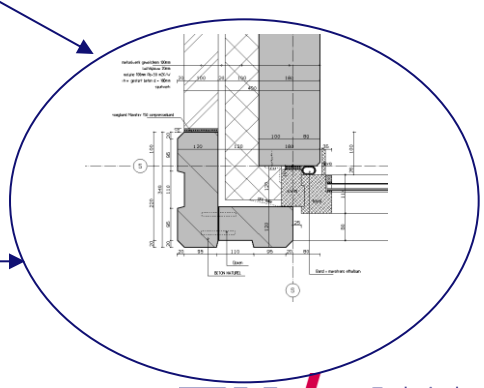
Where innovation starts

Background: Computational Building Physics
PSE: Problem solving environment

Multi Buildings
'HAMBase'
MatLab

Multi Systems & Control
ODE
SimuLink

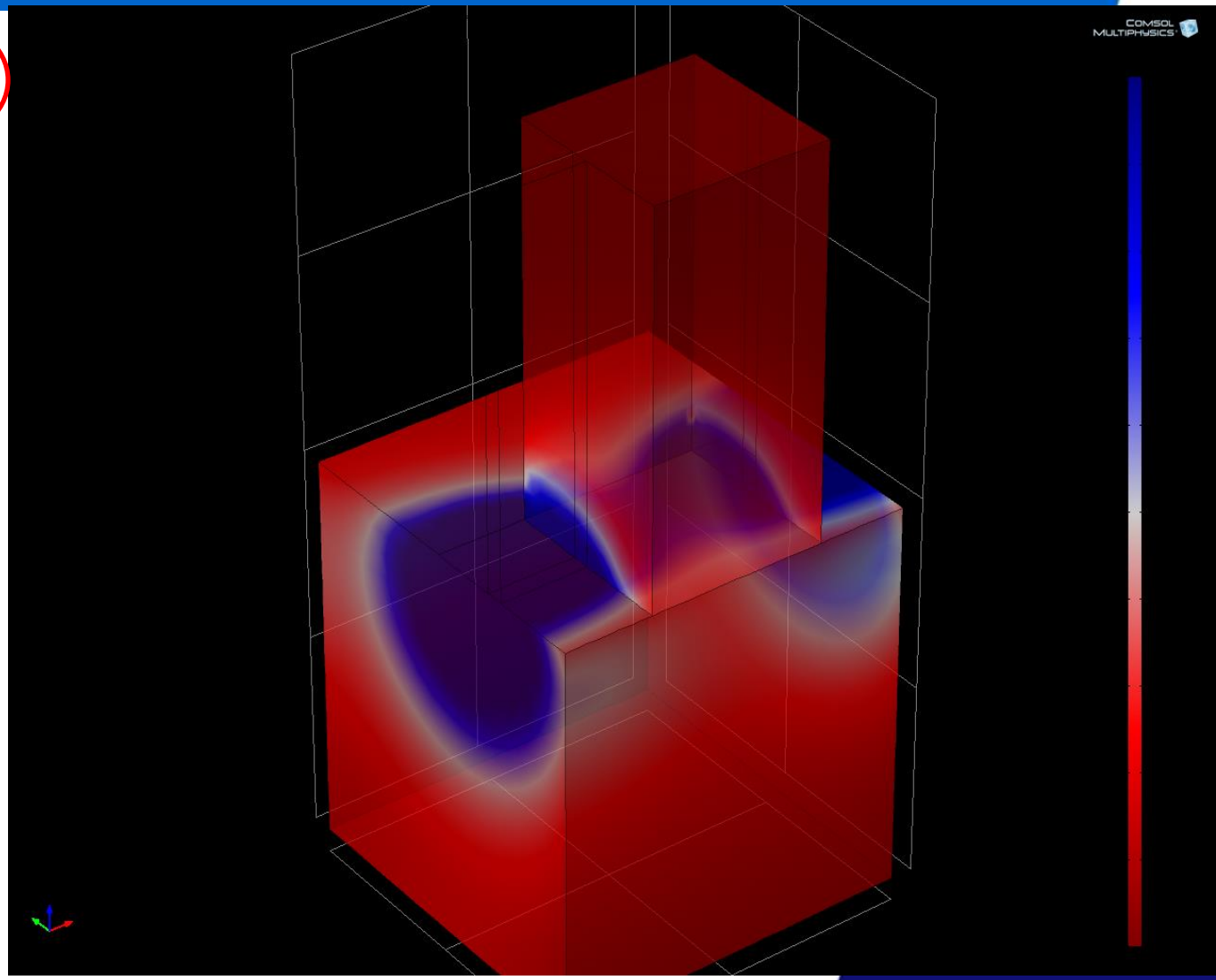
Multi Details
PDE
Comsol



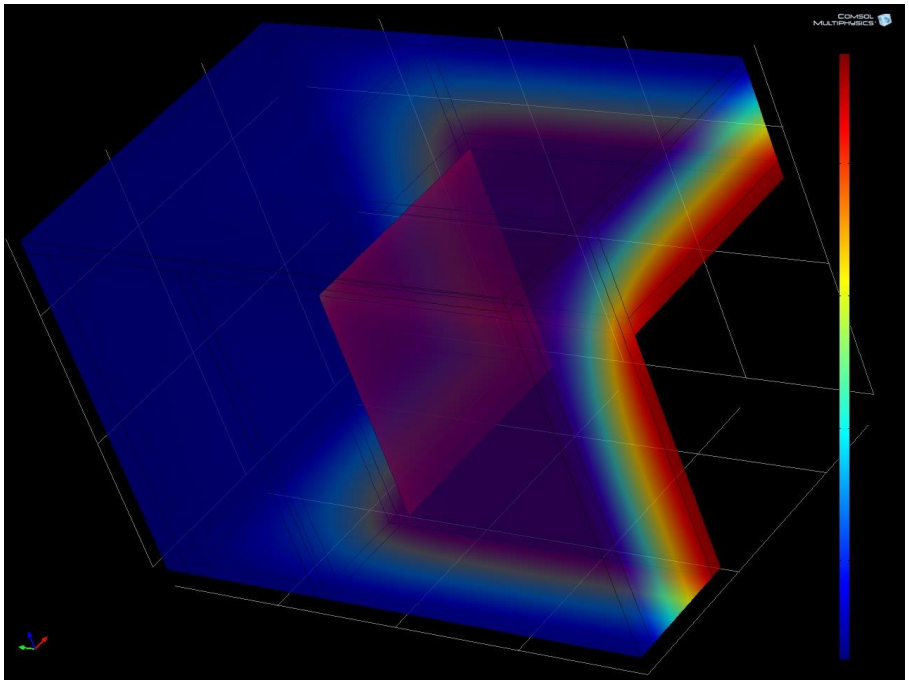
Background: Scale levels Building physics

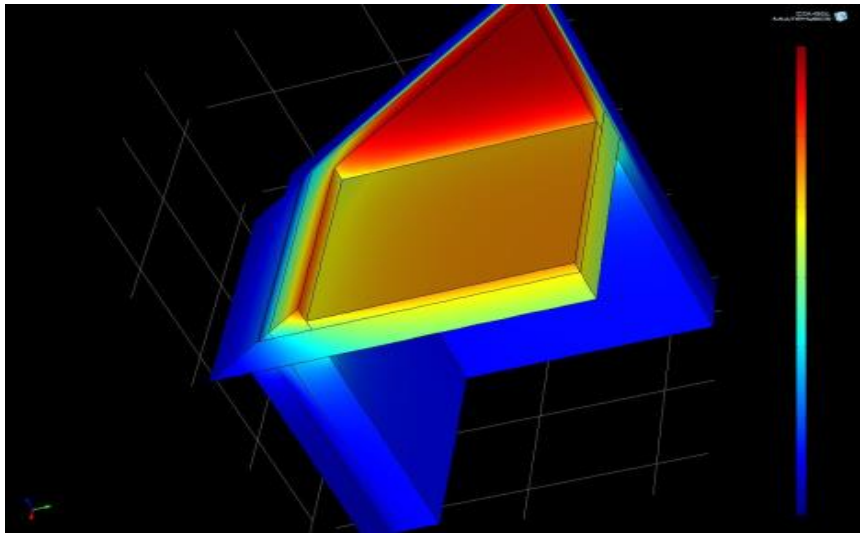
- [mm] Material Physics
- [m] Building Physics
- [km] Urban Physics
- [Mm] Climate Physics

Scale level [mm] Material Physics
Moisture induced damages

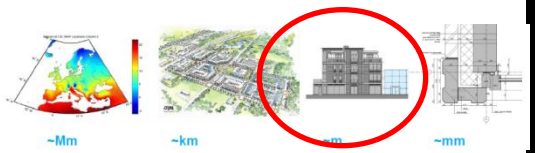


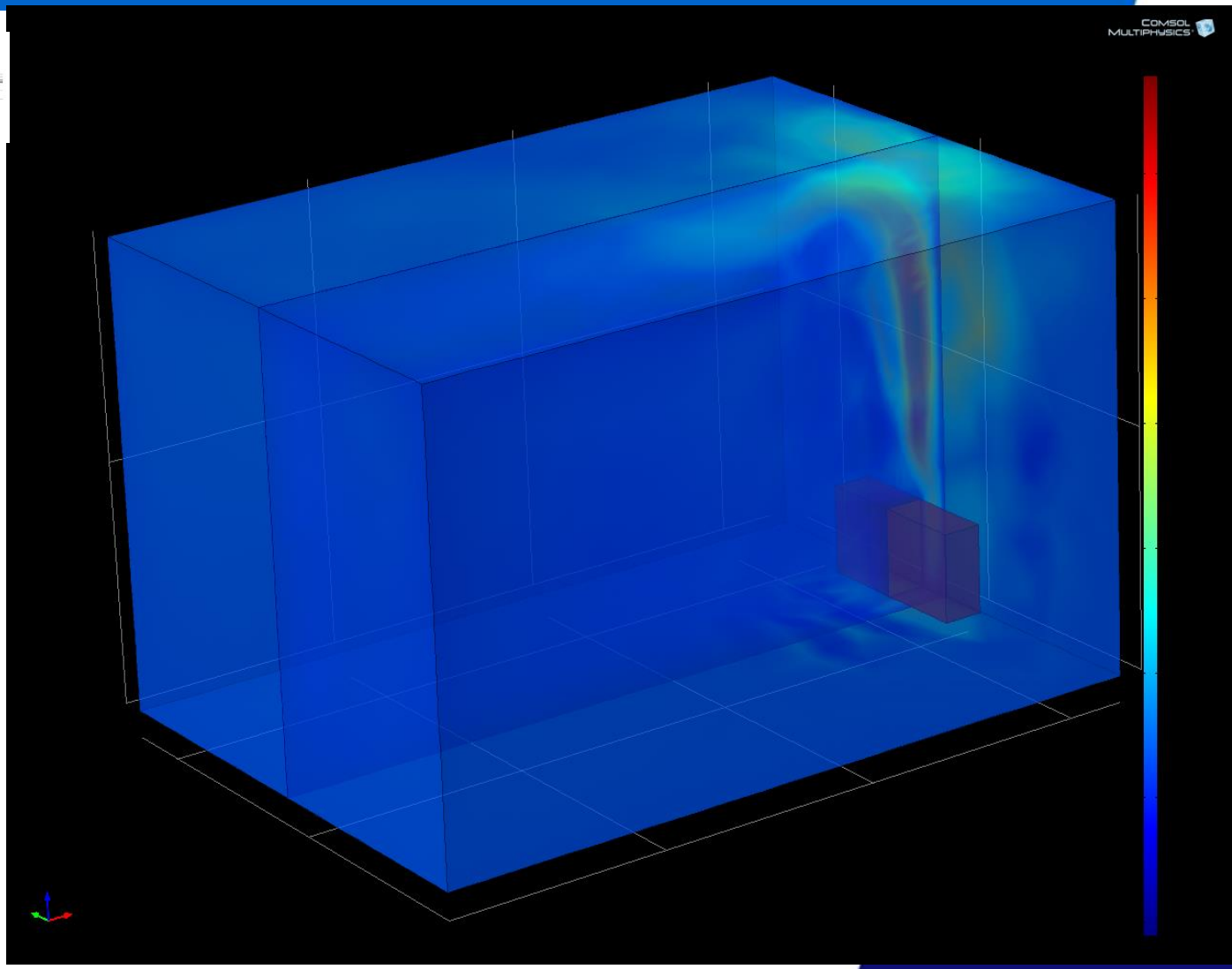
Scale level [cm] Building systems Physics Thermal bridges



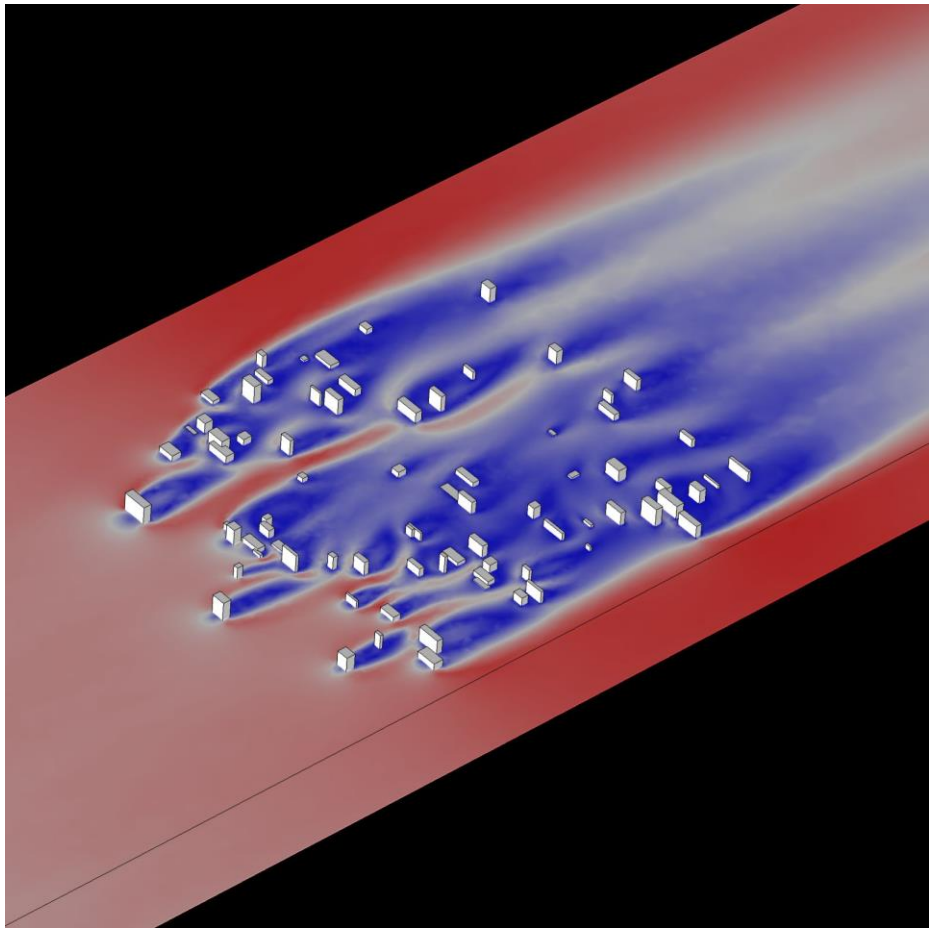


Scale level [m] Building Physics
Indoor climate performance & design

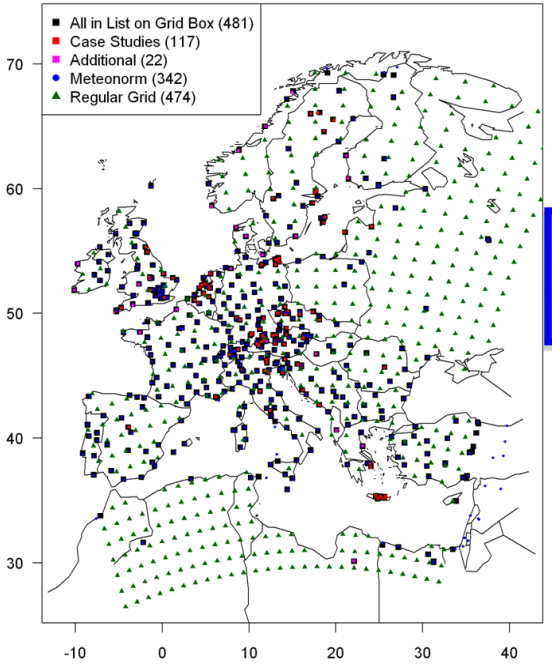




Scale level [km] Urban physics
Urban climate performance

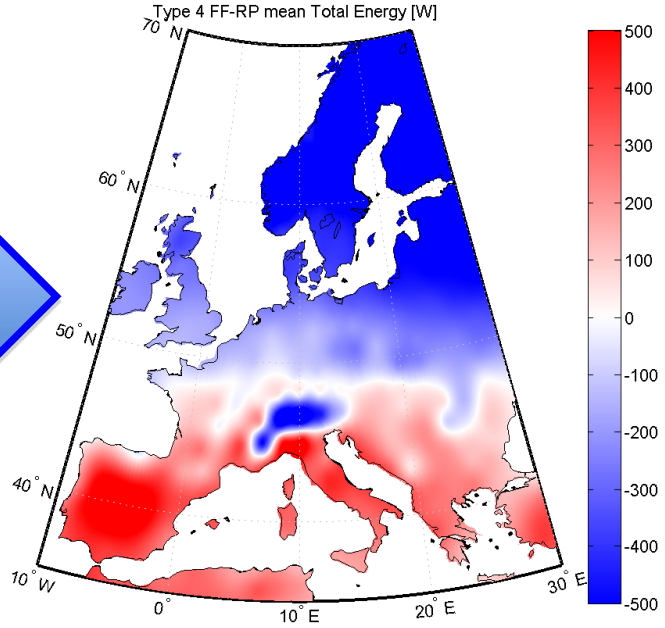


Scale level [Mm] EU physics
EU climate scale performance & design



Building simulation (HAMBase)

Museum models (Classification)



Academic Course on Research Methods

- **The basic idea is to introduce four common research methods:**
  - **Literature study**
  - **Experiment**
  - **Simulation**
  - **Data analysis**

to first year students.

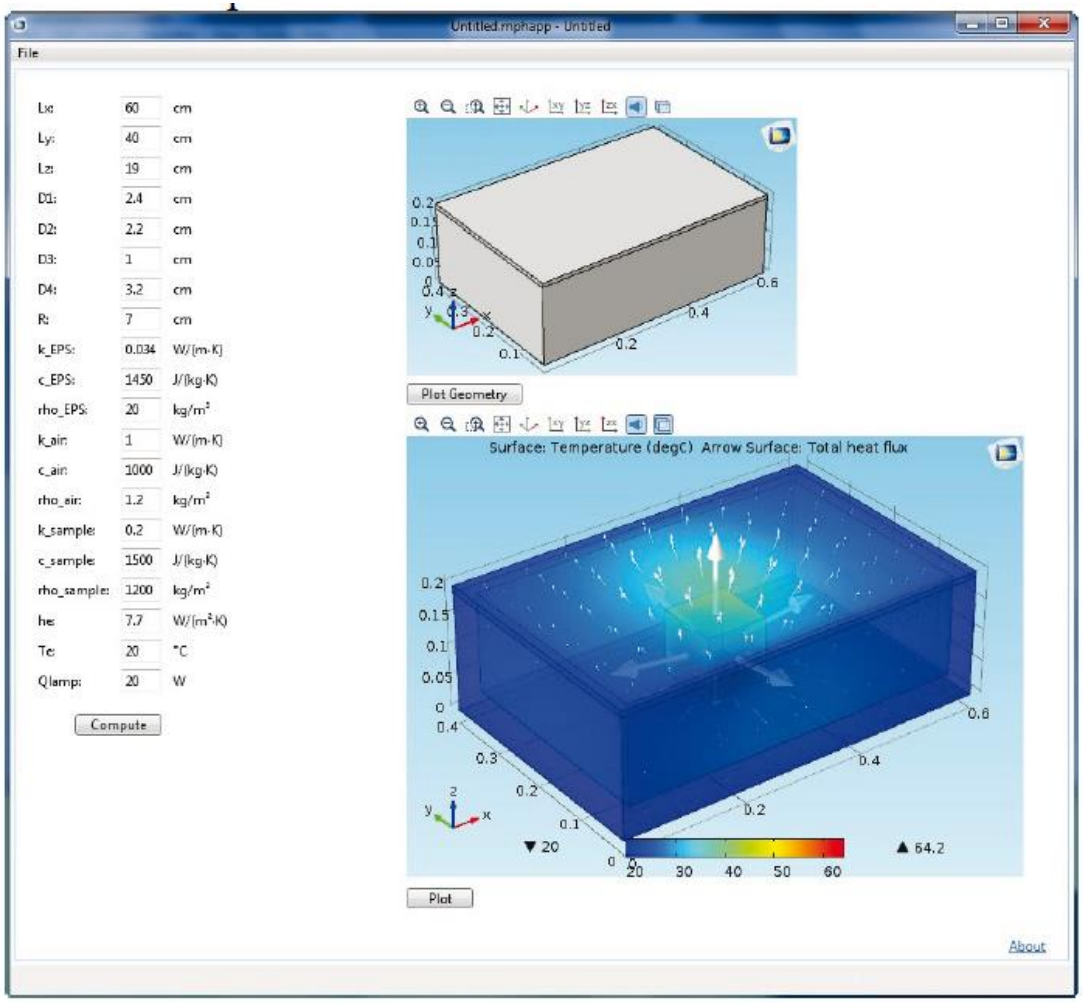
Academic Course on Research Methods

- **Rubrics**
  - **TT: Skills**
  - **ET: paper**

	Topic	Excellent	Good	Fair	Unacceptable
TT 7.5%	**Literature study skills**	Several reputable background sources were used and cited correctly.	A few reputable background sources are used and cited correctly.	Material is directly copied and background sources are cited incorrectly.	A few background sources are used and cited correctly, but some are not reputable sources.
TT 7.5%	**Simulation skills**	Students are provided with a realistic simulation of lab activities that can be customized for the final report	Students are provided with a realistic simulation of lab activities	Students are not provided with an accurate simulation of lab activity	Students did not provide any simulation
TT 7.5%	**Data Analysis skills**	The relationship between the variables is discussed and patterns logically analyzed. Predictions are made about what might happen if the experimental design could be changed.	The relationship between the variables is discussed and trends/patterns logically analyzed.	The relationship between the variables is not discussed.	The relationship between the variables is discussed but no patterns, trends or predictions are made based on the data.
TT 7.5%	**Experimental skills**	Experimental errors, their possible effects, and ways to reduce errors are discussed.	Experimental errors and their possible effects are discussed.	There is no discussion of errors.	Experimental errors are mentioned.
ET 10%	**Literature Sources**	Several reputable background sources were used and cited correctly. Material is translated into student's own words.	A few reputable background sources are used and cited correctly. Material is translated into student's own words.	Material is directly copied rather than put into students own words and/or background sources are cited incorrectly.	A few background sources are used and cited correctly, but some are not reputable sources. Material is translated into student's own words.
ET 20%	**Introduction**	Problem is clearly stated. Includes a detailed research section of the project.	Problem is stated. Research is incomplete.	Problem is not stated. Limited research section.	Missing research. Problem stated incorrectly.
ET 20%	**Methods**	Materials and Procedure are well explained in detail. Errors were discussed. Relevant figures were included.	Materials and procedures were partially explained. Some detail missing. Errors were not fully discussed. Figures were/were not included.	Materials and Procedures were not complete. Errors were not discussed. Figures were left out.	Materials and Procedure were not understandable. No figures included.
ET 20%	**Results and Conclusions**	Data tables and graphs included. Written explanation provided of data tables and graphs. Figures included. Conclusion discusses future research.	Some data tables and graphs included but more is needed. Partial explanation of tables and graphs. Limited figures. Conclusion is incomplete	Data tables and graphs are incomplete. Missing explanation of data tables and graphs. No figures. Conclusion is incomplete.	No data tables and graphs included. Conclusion is incomplete or missing.

Students Doing Simulation before Experiment

- **Students use a Comsol app**



Students Doing data analysis on the Simulated Sensor Output

- **Students Calculate heat conduction coefficient of the sample using the time series of simulated sensors**
- **This calculation method is identical if real sensors are used in the experiment**
- **Students compare the calculated heat conduction coefficient with the input value and learn that this is a verification.**

Students doing the Experiment

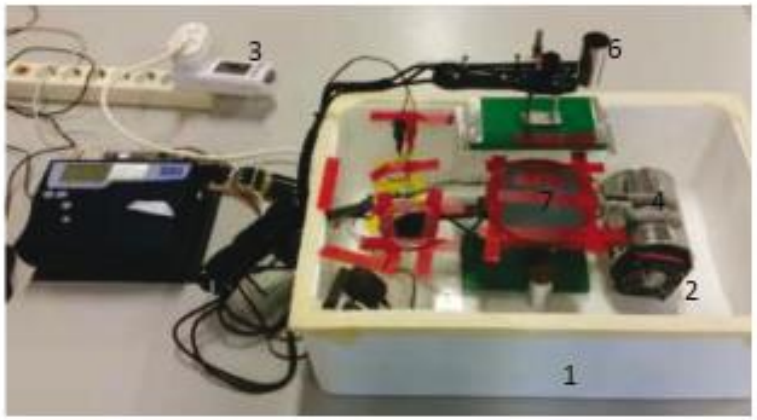
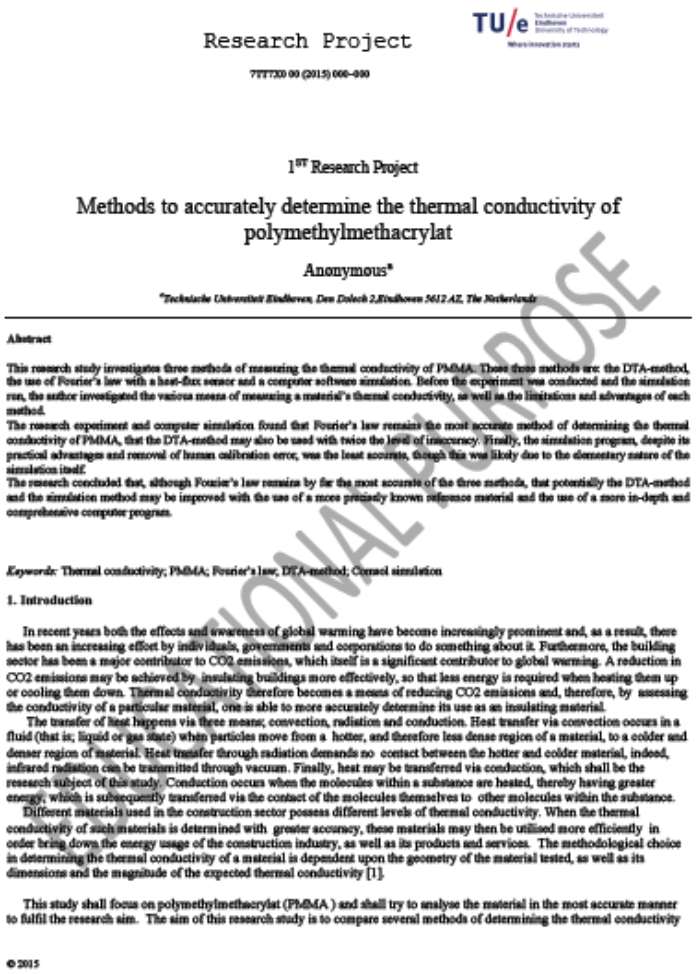


Figure 1. Setup of the experiment

Where:
1: EPS Box
2: Heat Source
3: Electrical Power Meter
4: Ventilator
5: Data logger
6: Thermo-couple
7: PVC reference sheet

Students write their first Scientific paper



Research Project

TU/e Technische Universiteit Eindhoven University of Technology

7TT720 00 (2015) 000–000

1ST Research Project

Methods to accurately determine the thermal conductivity of polymethylmethacrylat

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Abstract

This research study investigates three methods of measuring the thermal conductivity of PMMA. These three methods are: the DTA-method, the use of Fourier's law with a heat-flux sensor and a computer software simulation. Before the experiment was conducted and the simulation run, the author investigated the various means of measuring a material's thermal conductivity, as well as the limitations and advantages of each method.

The research experiment and computer simulation found that Fourier's law remains the most accurate method of determining the thermal conductivity of PMMA, that the DTA-method may also be used with twice the level of inaccuracy. Finally, the simulation program, despite its practical advantages and removal of human calibration error, was the least accurate, though this was likely due to the elementary nature of the simulation itself.

The research concluded that, although Fourier's law remains by far the most accurate of the three methods, that potentially the DTA-method and the simulation method may be improved with the use of a more precisely known reference material and the use of a more in-depth and comprehensive computer program.

Keywords: Thermal conductivity; PMMA; Fourier's law; DTA-method; Comsol simulation

1. Introduction

In recent years both the effects and awareness of global warming have become increasingly prominent and, as a result, there has been an increasing effort by individuals, governments and corporations to do something about it. Furthermore, the building sector has been a major contributor to CO2 emissions, which itself is a significant contributor to global warming. A reduction in CO2 emissions may be achieved by insulating buildings more effectively, so that less energy is required when heating them up or cooling them down. Thermal conductivity therefore becomes a means of reducing CO2 emissions and, therefore, by assessing the conductivity of a particular material, one is able to more accurately determine its use as an insulating material.

The transfer of heat happens via three means; convection, radiation and conduction. Heat transfer via convection occurs in a fluid (that is; liquid or gas state) when particles move from a hotter, and therefore less dense region of a material, to a colder and denser region of material. Heat transfer through radiation demands no contact between the hotter and colder material, indeed, infrared radiation can be transmitted through vacuum. Finally, heat may be transferred via conduction, which shall be the research subject of this study. Conduction occurs when the molecules within a substance are heated, thereby having greater energy, which is subsequently transferred via the contact of the molecules themselves to other molecules within the substance.

Different materials used in the construction sector possess different levels of thermal conductivity. When the thermal conductivity of such materials is determined with greater accuracy, these materials may then be utilised more efficiently in order bring down the energy usage of the construction industry, as well as its products and services. The methodological choice in determining the thermal conductivity of a material is dependent upon the geometry of the material tested, as well as its dimensions and the magnitude of the expected thermal conductivity [1].

This study shall focus on polymethylmethacrylat (PMMA) and shall try to analyse the material in the most accurate manner to fulfil the research aim. The aim of this research study is to compare several methods of determining the thermal conductivity

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