THESIS REVIEWER'S REPORT

I. IDENTIFICATION DATA

Thesis title:	**Deep learning-based modeling and simulation of heat conduction**
Author's name:	**Ondřej Šperl**
Type of thesis :	master
Faculty/Institute:	Faculty of Civil Engineering (FCE)
Department:	Department of Mechanics
Thesis reviewer:	Václav Nežerka
Reviewer's department:	Department of Physics

II. EVALUATION OF INDIVIDUAL CRITERIA

Assignment — **extraordinarily challenging**

The project undertaken in this thesis is highly demanding, requiring proficiency in advanced mathematics, computational physics, and programming. It merges deep learning with traditional numerical methods to tackle the complex problem of heat conduction modeling. The integration of physics-informed neural networks (PINNs) to solve partial differential equations and compare them with established methods such as the finite element method (FEM) and polynomial chaos demonstrates a high level of difficulty and innovation.

Fulfilment of assignment — **fulfilled**

The thesis fulfills the assigned task at an excellent level. The primary goals of implementing and assessing PINNs for heat conduction simulations were achieved. The student demonstrated an in-depth understanding of the topic and provided robust comparisons between PINNs and traditional numerical and surrogate modeling methods.

Methodology — **outstanding**

The approach and solution methods are correct and innovative. The use of PINNs to embed physical laws into the loss function to reduce dataset dependency is well-founded. The comparisons with FEM and polynomial chaos were methodologically rigorous and provided valuable insights into the strengths and limitations of the approach.

Technical level — **A - excellent.**

The thesis is technically sound. The student showcased skillful use of advanced mathematical concepts and programming tools to achieve the research objectives. The methodologies and experiments were conducted thoughtfully, with clear articulation of results.

Formal and language level, scope of thesis — **A - excellent.**

While the thesis is well-structured and clear, there are areas for improvement in formalisms and notations:

- Typographic errors, such as the comma after Equation 2.16 on a new line and the repetition of the word "physics" in Section 2.4.
- Units like degrees Celsius ("C") should not be written in math mode.
- When referring to size, "x" should be replaced by "$\times$" for the proper symbol, as seen in Figure 3.3.
- Captions should end with a full stop and not be split across lines.
  These details, though minor, are important in high-quality academic work.
- Some figure captions, such as for Figure 3.3, lack units for color bars or sufficient detail in the description.
- The text below Table 3.1 should be in the table caption, and table captions should use sentence case rather than title case.
- Inconsistencies in formatting, such as splitting Figure 3.3's caption into two lines, should be avoided.

- The conclusion section is divided into a single subsection, which is unnecessary.
- Some variables, like "y," are used with different meanings in the "numerical modeling" and "machine learning" sections, which could confuse readers.
- Certain phrases, such as "As you can see" in the results section, could be replaced with more formal language.

IMPORTANT NOTE: These shortcomings do not significantly impact the overall quality but should be noted for improvement.

Selection of sources, citation correctness	**A - excellent.**
The thesis provides a thorough review of relevant literature, effectively contextualizing the research. The selection of sources is appropriate, and the student clearly distinguishes their original contributions from previous work. The bibliographic citations generally meet academic standards, but consistent formatting and referencing (e.g., figures and tables with lowercase "f" and "t") should be ensured.	

Additional commentary and evaluation (optional)
The thesis is of exceptional quality, showcasing advanced technical knowledge, innovation, and rigor. I was impressed by both the theoretical part (well presented) and the practical part (advanced calculations). The integration of deep learning with physics-based modeling demonstrates significant novelty and has the potential for substantial impact in the field.

III. OVERALL EVALUATION, QUESTIONS FOR THE PRESENTATION AND DEFENSE OF THE THESIS, SUGGESTED GRADE

I evaluate the thesis as excellent across all categories and aspects. Although my comments may appear critical and detailed, they are not intended to highlight any shortcomings but rather to uphold the exceptionally high standard set by the quality of this work.

This thesis is of an exceptionally high standard, demonstrating mastery of advanced mathematics, programming, and physics-based modeling. Its contribution to computational modeling is significant, and the work could serve as a foundation for a high-quality PhD thesis.

Questions for the defense:

1. How does the computational efficiency of PINNs compare to FEM for large-scale problems?
2. Did you face any challenges during the implementation of PINNs, and how did you overcome them? Was it challenging to implement your own loss functions when using ML libraries in Python?

The grade that I award for the thesis is **A - excellent.**

Date: **15.1.2025** Signature: