Review of: "Tailoring the First Law of Thermodynamics for Convective Flows"

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Potential competing interests: No potential competing interests to declare.

Karol Makuch's article, "Tailoring the First Law of Thermodynamics for Convective Flows," offers an innovative approach to generalizing the first law of thermodynamics to non-equilibrium systems, particularly those involving convective flows. This work is part of an ambitious effort to extend the well-established principles of equilibrium thermodynamics to more complex systems where temperature gradients and energy fluxes are not uniformly distributed.

The article is meticulously structured, beginning with a clear presentation of the central problem: how can we describe energy exchanges in non-equilibrium systems with the same simplicity and accuracy as in equilibrium thermodynamics? This fundamental question is at the heart of the paper, and the author addresses it with a depth of conceptual understanding that reflects a strong command of the subject. The introduction highlights the importance of developing theoretical frameworks suitable for dynamic systems, which could have significant implications in fields as diverse as meteorology and industrial processes.

The second section focuses on the global energy balance equations for closed systems. The mathematical derivations, grounded in principles such as Gauss's theorem, are executed with rigor, demonstrating the robustness of the author's theoretical foundations. This part of the text is crucial for understanding how non-equilibrium systems can be modeled coherently and precisely.

In the third section, the author explores steady states and the transitions between these states, generalizing the first law of thermodynamics. The author elegantly shows how, under certain conditions, the results reduce to the classical laws of thermodynamics, highlighting the continuity and robustness of the approach. This section offers intriguing perspectives for those looking to model complex systems while maintaining an approach rooted in proven principles.

Finally, the fourth section delves deeper into specific contributions to the energy balance, explaining how these concepts can be applied to dynamic systems. The analysis is precise and demonstrates a genuine commitment to extending the boundaries of classical thermodynamics.

Thoughtful Recommendations

1. Clarifying Assumptions: To further enhance the clarity and accessibility of the article, it might be helpful to make the assumptions underlying each derivation even more explicit. This would guide readers through the complex reasoning

steps, making the article more approachable even for those less familiar with the field.

2. Incorporating Concrete Examples: The article could benefit from including concrete examples or case studies that illustrate the practical application of the proposed theories. These examples would allow readers to more easily visualize how the theoretical concepts translate into real-world situations while also highlighting the relevance of the work.
3. Improving Structure with Subheadings: To further improve the article's organization, introducing subheadings within the main sections could help segment complex ideas and provide better navigation for the reader. This would also make it easier for those seeking specific information to find it within the text.
4. Expanding the Discussion of Implications: A more in-depth discussion of the implications of the results obtained and potential future research directions could enrich the article’s conclusion. This would further underscore the importance of theoretical contributions while offering exciting avenues for future exploration.
5. Experimental Perspective: Finally, although the article is primarily theoretical, considering an experimental validation of the proposed models could be a natural and exciting next step. This would strengthen the credibility and applicability of the developed theories by grounding them more firmly in scientific reality.

Overall, this article represents a significant advance in understanding non-equilibrium thermodynamic systems. With a few minor adjustments, it could gain even more impact and clarity, paving the way for exciting new research in this rapidly evolving field.