Review of: "Classical Thermodynamics: Primacy of Dissymmetry Over Free Energy"

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This paper provides stimulating reading, among other things, by the wealth of historical references. An important, and often forgotten, aspect that is emphasized in the paper is the engineering background of the historical development of classical thermodynamics. Indeed, a central question in classical thermodynamics, directly motivated by the development of the steam engine, is how to generate mechanical work using heat. Furthermore, adding to this engineering origin, the systems considered in classical thermodynamics are open to interaction with their surroundings, e.g., by heat reservoirs or by performing mechanical work on other systems.

The First Law identifies heat and mechanical work as manifestations of a common quantity called energy, which is preserved or exchanged with the surroundings. However, soon in the development of thermodynamics, it was realized that heat cannot be arbitrarily converted into mechanical work. This led to the Second Law. A main issue addressed in the current paper is the proper formulation of the Second Law. In fact, it is suggested in the paper that, starting from the work of Thomson (Lord Kelvin), 'free energy' should be used for the formulation of the Second Law. At this point in the paper, I believe closer attention to the treatment of the Second Law and to the definition of entropy as given in the classical treatise "Thermodynamics' by Fermi [1] would have been helpful. In fact, Fermi gives the following statement of the Second Law, which he attributes to Kelvin:

"A transformation of a thermodynamic system whose only final result is to transform into work heat extracted from a source which is at the same temperature throughout is impossible".

A direct consequence of this formulation of the Second Law is that whenever the temperature of the heat source is kept constant, the thermodynamic system cannot produce positive mechanical work; i.e., the free energy is decreasing, as also emphasized in the present paper. On the other hand, this formulation of the Second Law is *stronger* than the decrease of free energy for each constant temperature. Namely, Kelvin's formulation also forbids the conversion into work of heat from a source at constant temperature with respect to all transformations in which the system interacts as well with a *second* heat source at another temperature, as long as the net heat taken from this second heat source is zero. In fact, this additional implication of the Second Law is crucially used in the discussion of the Carnot cycle and in the ensuing definition of entropy by Clausius, as detailed in the book by Fermi [1]. See also the paper [2] for a very much related treatment.

Overall, the paper provides stimulating reading, but could have been more to-the-point at various places. Often, it is not crystal clear where the author is exactly heading, and there appear to be quite a few digressions that are not really helpful for the understanding of the main line of the paper.

[1] E. Fermi, Thermodynamics, Prentice-Hall, 1937, Dover edition, 1956

[2] A. van der Schaft, Classical thermodynamics revisited; a systems and control perspective, IEEE Control Systems Magazine, October 2021, pp. 32–61.