

## The Fourth Law of Thermodynamics<sup>@</sup>

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**Delivering the Salim Ahmed Memorial Lecture during PIP Conference, Lahore, March 28-30, 2011**



**With Vice Chancellors of UoP<sup>†</sup> (Center) and UET during Conference Dinner on March 29**

This paper discussed difference between equilibrium, steady state and non-equilibrium both in terms of energy transfer as well as probability of occupation. Thermodynamic equilibrium (two bodies, at the same temperature, brought into thermal contact shall not exchange energy — no flow of heat), is a dynamic equilibrium. Every object is emitting and absorbing thermal radiation. If the rates of emission and absorption are equal, the object shall remain at the same temperature — it is said to be in thermodynamic equilibrium. In terms of energy transfer, equilibrium implies no net transfer of energy/data/information, *e.g.*, curfew imposed in the city, no traffic on roads, steady state implies transfer of energy/data/information at a uniform rate, *e.g.*, traffic on motor way and non-equilibrium implies transfer of energy/data/information at a variable rate, *e.g.*, traffic in Empress market. Steady state is the optimal solution in information processing, traffic management, electric transmission, heat exchangers and international politics. In terms of probability of occupation, equilibrium implies same probability of occupation in different states, which is not varying with time, steady state means different probability of occupation in different states, but not varying with time, whereas non-equilibrium corresponds to probability of occupation in different states varying with time. Examples from thermodynamics, electrodynamics and international relations were discussed. The paper, then, reviewed the zeroth, the first, the second and the third laws of thermodynamics. The existence of negative temperatures in small, isolated subsystems does pose a question whether the first law would remain valid if one is able to construct a heat engine, which uses these states as sink. In this case, a *Carnot Engine* operated with such a heat sink may have an efficiency exceeding unity (violation of the first law of thermodynamics). Such negative-temperature states were discovered in nuclei of atoms of solid arranged in a lattice shape. These nuclei constitute a subsystem of the solid, which are isolated from the rest of the solid by perfect vacuum existing between the nuclei and the electrons of an atom. Although, at this stage it seems, almost, technologically impossible to operate a heat engine involving such a system, quantum tunneling and processes similar to Hawking radiation may be discovered in future, which make operation of such an engine possible. In order to avoid logical inconsistencies, the fourth law of thermodynamics was presented: “It is not possible to run a *Carnot Engine* or any other physical heat engine between a source having a positive (absolute) temperature and a sink having a negative (absolute) temperature”. This lecture was dedicated to the loving memory of the speaker’s teacher and inspirer, (Late) Salim Ahmed, who taught him courses entitled Theory of Relativity and Methods of Mathematical Physics as faculty member of Department of Physics, University of Karachi. He, then, proceeded to United States for his graduate studies. At the time of his death, he was associated with Hamdard University.

**Keywords:** Heat engine • Negative temperatures • Steady state

**Grant Sponsor:** Dean’s (Science) Research Grant, University of Karachi, number DFRS/2009

**Web address of this document:** <https://www.ngds-ku.org/Presentations/Thermodynamics.pdf>

**Full paper:** <https://www.ngds-ku.org/Papers/C83.pdf>

<sup>@</sup>The motivation of this paper was a question by BS First Year Student of Mathematics (Evening Program — Class of 2013), Syed Ghulam Murtaza, regarding the possibility of using negative-temperature-isolated subsystems as heat sink.

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