U. Kivi

Thermodynamics

Ideal Gas Basic Theory

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CONTENT

FOREWORD

Coffee, roll and sudoku in swimming hall cafe or in some other common cafe constitute an essential part of my swimming hoppy. Sudoku was gradually replaced by Einstein's relativity theory calculations about five years ago. One reason for the change was that a family with children moved to the residence beneath my residence. The children made unbearable noise every evening, so I began to hang in cafes late almost every evening and calculated physics. In couple of years the noise was reduced essentially – due to complaints of some of my neighbors. But I continued with my new calculation hoppy, now increasingly also at home. I had of course been interested in relativity theory and other fields of physics also before, but my main action was only to read appropriate literature. To my surprise I could attain new results, and published the results in a book (U. Kivi 'Painovoima, Newtonin ja Einsteinin teoria helpolla tavalla'and the English translation U. Kivi: 'Gravitation, Exact calculation of Newton and Einstein theory'). I don't know yet whether the results presented in the 'Gravitation' book are worth anything, but if they are, they are not my first achievements in the field of physics/mathematics. Although I have published nothing, I obtained some remarkable accomplishments already in 80's, when I began my career in nuclear field. I have listed my most important achievements in appendix 1 as labours of Joracles. This book is linked with the labour number 1. As an initiator and adviser for that labour acted my boss of that time. As a theoretical physicist and mathematician I could formulate his ideas got by examining steam tables into form of mathematical algorithms. As a result we got a new way to calculate the pressure of air-steam-water –mixture. The method lies on a very firm ground, because it is based on the laws of conservation of mass and energy. Success creates success and encouraged by this achievement and supported by my boss I started to solve also other mathematical problems in my job domain and achieved good result as is presented in appendix 1.

Without those successes presented in appendix 1 I would hardly have had the courage to begin to solve the equations of general relativity. Relativity theory solutions do not have such economic significance as the mathematical algorithms presented in appendix 1, but as an a bit original view of solving gravitation the theory presented in the 'Gravitation' -book hopefully promotes the development of physics as a science (or maybe not if it turns out to be pure grab). Inspired by the 'Gravitation' –book I decided to write also a book about thermodynamics. Relativity theory does not have any connection to my profession, but with thermodynamics I spent a large part of my first professional years.

As a student I was a bit disappointed to notice that my understanding of the fundamental structure of classical thermodynamics was rather weak after the course of statistical physics at Technical High School. As I began my professional career, one of my first tasks was to examine the pressure and temperature behavior of Loviisa nuclear power station containment in an accident that is called loss of coolant accident. In this accident the main circulation pipe of reactor coolant water is broken and hot water and steam discharge into the containment. This is typical problem in the field of thermodynamics. Of course this situation had been analyzed with the help of computer calculations in the design materials of the power station, but at that time even individual computer runs were expensive, so we decided with my boss to make our own computer program for thermodynamic calculations. The program was completed and we could vary among other things the size of the leak, the amount of heat flow into structures, function of ice condenser and the function of the containment spray system. With the help of the program we could examine the accident situation more thoroughly than was done in design material and we could also verify the design calculation results. Our calculations indicated that the design calculations had been performed in a very firm way or conservatively, if we use our professional term.

Because the theory of thermodynamics was not easy to understand for me (I suppose that it was not easy for almost anybody), I had to deliberate also the foundations of the theory. Often the most efficient way to understand the foundations of some theory is to consider the simplest possible model, which in the case of thermodynamics is the ideal gas model. I present in this book the ideas that I got when making the thermodynamics program and also some ideas that matured slowly at later years. The ideas are mainly applied for the ideal gas calculations.

Helsinki 31.1.2020
Joracles alias Uuno Kivi alias Jorma Rantakivi

1. INTRODUCTION

Thermodynamics deals with properties and relations of quantities known to everybody (temperature, pressure, density). The need to understand the function of thermal power machines (such as steam engine) gave the impulse to develop the theory. Energy was found to be the fundamental quantity of the theory and it governs the thermodynamic properties of mater in form of heat or mechanical energy. Thermal power machine is able to convert heat to mechanical energy. The theory of thermodynamics was needed to optimize the function of the thermal power machines in such a way that the gain of mechanical energy would be maximized. It turned out that the quantities introduced above were not enough to create a functional theory, but additionally a new more abstract quantity was needed to describe the thermodynamical state of a system. The new quantity was named entropy. The theory of thermodynamics and kinetic theory of gases was developed in 1800 century and at the beginning of 1900 century. The new quantity – entropy – and its physical interpretation had a central role in that development. Entropy turned out to be a measure for the disorder of a system. The smaller the entropy the more ordered the system is. Because physical processes have a natural tendency to go towards higher disorder, entropy was found always to increase or stay constant. Entropy may decrease in a subsystem of a larger system, but if one considers the entropy of the whole system, it either increases or stays constant. If we for example have two containers filled with gas and having different temperatures in contact with each other, heat flows from the gas with higher temperature to the gas with lower temperature and the entropy of that gas that is cooling decreases, but this is compensated by entropy increase of the gas that warms up.

I was especially irritated by the fact that you did not know the functional relationships between the different quantities even in the case of ideal gas thermodynamics. Only relationships of certain partial derivatives of the quantities were available. Because of this the theory in a way hanged in the air and mastering the theory seemed to demand a long-term practice in manipulating the appropriate formulas. So I tried solemnly to develop functional formulas between the different quantities to make the theory more concrete. I succeeded in doing this and it was surprisingly easy and the functional relationships are presented in chapter 5 'Ideal gas'. Now I have to say that I know the thermodynamic literature so poorly that I cannot claim that these formulas would be quite new, but they seem to be missing at least in the older thermodynamic textbooks.

In chapter 6 'Ideal gas thermodynamic processes' I construct the needed calculation formulas and describe the development of processes, when two of quantities pressure, volume, temperature or heat transfer are given as functions of time. I hope that this chapter helps especially those people (for example students) that begin to familiarize themselves to thermodynamics. A thermodynamic process is calculated step by step using small time steps. A special feature of the method used in this book is that the two quantities given as functions time are allowed to change simultaneously. Normally the calculation is performed so that one of the quantities is kept constant while changing the other one. The result depends on the value of the time step and to get an accurate result you have to use a small enough time steps. One may assume that the dependence on the value of the time step is not so strong with the method used in this book compared to the normal method. If the dependence of the given quantities on time is not linear, the desired accuracy may be reached by using small enough time step. A Fortran program is listed in appendix 2 with the help of which you may calculate the state of an ideal gas system, when two of quantities pressure, volume, temperature or heat transfer are given as functions of time. You may choose two out of four in six ways so there are six different calculation cases. An example calculation is performed for each case. The result is given as graphs and an explanation for each graph is given. As the last case the program is used to calculate the famous Carnot process.

The basic theory of thermodynamics is treated in the book using ideal gas as an example. A clear explanation for the quantity entropy is given in the book. Analytic formulas for the mutual functional dependence of the quantities volume, pressure, temperature and entropy are given in the book in the case of an ideal gas. A thorough treatment of ideal gas thermodynamic processes is presented in the book. In a process two quantities are given as functions of time and other quantities are calculated as functions of time. I hope that the thorough treatment helps especially those people (for example students) who take their first steps in learning thermodynamics. The book includes a list of a computer program that calculates basic thermodynamic processes for an ideal gas. An example calculation for every process is presented in the book – input file is given and the result is presented as curves. Every curve is given a thorough description.

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