Chapter 2
Foundations of Thermodynamics

In Chapter 1 mathematical facts are dealt with exclusively. Now we are going to the physics of it. We may mention several important preliminaries, usually treated shabbily. We start to talk with the term energy and use the term system in this chapter without having it defined before. However, the term system is discussed soon afterward. Thus, we do not talk about the individual terms here in an axiomatic way. An axiomatic introduction into thermodynamics is, if it is possible at all, quite more difficult to understand. It is unnecessary to say that there are many impressive textbooks in thermodynamics [1–6].

2.1 Idealization

A few comments on idealization are in order here. We obtain physical laws by abstracting reality. Often, only the concept of simplification of the real world by abstraction allows a mathematical description of a physical phenomenon. On the other hand, problems and inconsistencies arise by the simplification procedure. Here we present some examples:

An ideal gas is abstracted as a couple of points that are moving freely in a confined space. The points have a zero extension in space. Further, they do not exert mutual forces. It is highly understandable that points with a zero extension would not be a source of forces. However, even when the points have zero extension, they carry mass. Therefore, applying common sense, we conclude that each point must have an infinite density. Moreover, these points show a heat capacity.

On first glance, this fact is also not understandable. However, if we are accustomed that the points have mass, then we could accept that the heat capacity is caused by the kinetic energy. This is in order again as we restrict ourselves to a translational energy.

We present still another example, Newton’s law of motion. This law states that under the action of force a particle will undergo acceleration. The acceleration is inversely proportional to the mass. In the treatment, often the particles are considered as point masses, as in an ideal gas.
These innocently looking assumptions run into problems, if we extend the concept of force to the concept of energy. If we observe a particle at a short moment we do not know how much energy the particles are possessing. However, if we observe the path of a particle, then we can state how much energy it has gained or lost when moving along the path. The energy is the path integral, in one dimension, we find

\[ U = -\int F(x)\,dx. \]  

On the other hand, we can trace back the energy to the force:

\[ F = -\frac{dU(x)}{dx}. \]  

If we are approaching the concept of force from the energy view \( U(x) \), we can state about the energy without knowing the force at all. If we are treating the energy as the basic quantity, the question arises as to how a point-shaped particle experiences that in a small distance; apart from the particle there exists a smaller energy and it could move to the position where the smaller energy is.

In other words, a point-shaped particle does not know about the gradient of the energy. We could introduce the concept that the point-shaped particle does not stand in its position, and the motion is fluctuating around a certain position. In this way, the particle could find out that besides its instantaneous position is a place where it would possess less energy. On the other hand, an extended particle in space could experience a gradient of the energy in space.

In common sense, we are accustomed to such gradients. If a drinking glass is positioned near the border of the table plate, a lot of people intuitively feel to place the glass more in the center of the table, to prevent it from falling down. This mental dictate emerges because it is believed that somebody could push the glass unintentionally and so cause the glass to reach the border and fall down eventually. If there would be nobody who could touch the glass unintentionally, then the habit to center a glass on the table is completely unnecessary. The glass would not fall down, no matter how high the table is.

### 2.2 Energy

Energy has the physical dimensions of \( \text{kg}\,\text{m}^2\text{s}^{-2} \). From its nature, energy is a nonnegative quantity. From a thermodynamic system, we can withdraw all the energy available, but we cannot borrow energy that is not there. For this reason, the energy has an absolute zero. If we deal with the energy available, then we mean the energy that is accessible to us from a system. A system may still contain energy that is not accessible to us by the tools we have.

For example, if we have a gas in a container with a piston, we can access the energy of expansion. If the container is adiabatically insulated, we cannot access the