2

The Zeroth and First Laws of Thermodynamics

Law: The body of rules governing the affairs of man within a community or among states; common law: the law of nations. Often plural: Principles of conduct perceived to be of natural origin.

(Am. Heritage Dict. of English Language)

2.1 Introduction

Just as Society is built upon the foundation of its laws, so is a field of Science. There is, however, a difference: Society's laws express man's collective wisdom; Science's laws express Nature's 'wisdom'. Thus the Laws of Thermodynamics express Nature's wisdom, as of course perceived by humans, and were developed in two stages:

First, observations of a variety of physical phenomena led men to conclude that there is a 'common reason' behind all of them, dictated by Nature and not by the way they are carried out. They arrived, thus, at a verbal statement of this common reason such as, "Energy is Conserved".

Second, this verbal statement was expressed analytically so that quantitative results can be obtained. Thus, "Energy is Conserved" becomes: \( Q = \Delta U + W \).

These analytical statements of the laws led eventually to the development of a 'framework' of equations that are used to solve all thermodynamic problems.

The whole process - from the collection and interpretation of the observations to the development of the framework of equations - was a very lengthy one, as we will see in Chapter 4, where we consider the historical development of the laws of thermodynamics. And this should be kept in mind as we proceed: it is not easy to comprehend and assimilate in a limited amount of time, what took hundreds of years to develop.

We will discuss the Zeroth and First Laws in this Chapter, and the Second Law in the following one. The Third Law is of more limited application; it will be stated in Chapter 4 and used in Chapter 15.
2.2 Objective and Approach

There are two main objectives in this Chapter:

First, to introduce, through the zeroth law, temperature as a state property rather than a physiological sense of 'hotness' and 'coldness'.

Second, to develop familiarity with the first law, its formulation and its applications.

We will start with the statement of the zeroth law, use it to establish temperature as a state property, and proceed to develop the ideal gas temperature scale.

We move then to the first law and discuss its development and analytical expression, especially the form that is convenient for steady-state flow processes that are typical in Chemical Engineering practice.

Since applications of the first law involve calculations of work and heat through evaluation of internal energy and enthalpy changes, we proceed to review briefly the fluid for which such changes are the easiest to determine: the ideal gas.

We close with some Examples and a few Concluding Remarks.

2.3 The Zeroth Law and the Ideal Gas Temperature

2.3.1 The Statement

We know from experience that a piece of wood and one of copper sitting in our back yard for a long time have the same 'hotness' as that of the atmosphere around them. Or, more generally: If bodies $A$ and $B$ are in thermal equilibrium with a body $C$, then they are in thermal equilibrium with each other.

Thermal equilibrium results when two bodies are brought into thermal contact through a diathermal wall, i.e. a wall that allows the flow of energy between the two bodies. The important point to notice here is that bodies $A$ and $B$ are in thermal equilibrium without having been brought into thermal contact with each other.