1.2: The Zeroth Law of Thermodynamics

This can be stated as follows.

Zeroth Law of Thermodynamics:

If two bodies A and B are in thermal equilibrium with a third body C, then they are in thermal equilibrium with each other.

Consequences of the Zeroth Law

Thermal equilibrium of two bodies will mean a restrictive relation between the thermodynamic coordinates of the first body and those of the second body. In other words, thermal equilibrium means that

$$F(\overrightarrow{x_A}, \overrightarrow{x_B}) = 0 \tag{1.2.1}$$

if A and B are in thermal equilibrium. Thus the zeroth law states that

$$\left.\begin{array}{l} F(\overrightarrow{x_A}, \overrightarrow{x_B}) = 0 \\ F(\overrightarrow{x_B}, \overrightarrow{x_C}) = 0 \end{array}\right\} \Rightarrow F(\overrightarrow{x_A}, \overrightarrow{x_C}) = 0 \tag{1.2.2}$$

This is possible if and only if the relations are of the form

$$F(\overrightarrow{x_A}, \overrightarrow{x_B}) = t(\overrightarrow{x_A}) - t(\overrightarrow{x_B}) = 0 \tag{1.2.3}$$

This means that, for any body, there exists a function $t(\vec{x})$ of the thermodynamic coordinates $\vec{x}$, such that equality of t for two bodies implies that the bodies are in thermal equilibrium. The function t is not uniquely defined. Any single-valued function of t, say, $T(t)$ will also satisfy the conditions for equilibrium, since

$$t_A = t_B \Rightarrow T_A = T_B \tag{1.2.4}$$

The function $t(\vec{x})$ is called the **empirical temperature**. This is the temperature measured by gas thermometers.

The zeroth law defines the notion of temperature. Once it is defined, we can choose $n+1$ variables $(\vec{x}, t)$ as the thermodynamic coordinates of the body, of which only n are independent. The relation $t(\vec{x})$ is an equation of state.

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