

Thermodynamics Zeroth Law

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The fundamental quantities related to the Zeroth Law of Thermodynamics are temperature and heat. In principle, “temperature” designates the level of heat while “heat” is the energy passing from one body to another by a thermal flow process due to a temperature difference. Temperature is one of the following basic physical properties-length, mass, time, electric current, and luminous intensity-in terms of which all other physical properties are defined, as well as the thermal equilibrium of two systems. The lower limit of temperature, which is not accessible according to the Third Law of Thermodynamics, is -273.15°C (Figure 1), while theoretically there is no upper limit to temperature. The origin of the word is from the Latin word *temperamentum* which indicated, according to Aristo, the four basic properties of matter: heat, cold, humidity and dryness. The first to distinguish between the level of heat and its quantity was, probably, El-Kindy, in the 9th century. Until the 17th century, the concept of temperature was ambiguous since no methods were known for the quantitative determination of the level of heat. Man’s first instrument for sensing hot and cold was his hand. At about 1600 several scientific workers realized that man’s temperature sense was inadequate. It is believed that the Italian scientist Galileo Galilei (1564-1642) was the first to construct a thermometer, while other scientists, including Santorio Santorio (Italian), Robert Fludd (English), and Cornelis Drebbel (Dutch), worked independently on similar devices at about the same time. Pavia C. Renaldini, was the first at 1694 who choose to use melting ice and boiling water as constant points of the temperature scale



Figure 1: The lower limit of temperature.



Figure 2: Constant points of the temperature scale.

(Figure 2). At 1742 Andres Celsius divided the interval between the above points in a mercury thermometer to 100 degrees corresponding to the so-called practical scale. Today there are two scales: the Celsius, or centigrade scale ($^{\circ}\text{C}$) and the Fahrenheit scale ($^{\circ}\text{F}$). The other scale is the thermodynamic scale, which assumes the existence of an absolute scale of temperature, the Kelvin scale (K) or the Rankine scale (oR), which have a lower limit, the absolute zero, 0 K. This limit corresponds to the absence of atomic and molecular motion, is independent of the kind of substance, and is based on Carnot’s reversible cycle efficiency, $T_1/T_2=Q_1/Q_2$. By measuring Q_1 and Q_2 and fixing, say T_1 , it is possible to determine T_2 .

Some typical temperatures are demonstrated via art. The lowest temperature, -273.15°C , is demonstrated by a spectacular photograph of Walter Wick, American photographer, of a snowflake crystal, about 20 times their actual size, which looks like perfect with respect to



Figure 3: The triple point of water.



Figure 4: Water vapor in equilibrium.

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symmetry. The ice point (water), 0°C , is demonstrated by a photograph of frozen berries. The triple point of water, 0.01°C (Figure 3), where ice, water, and water vapor co-exist, is demonstrated by the artwork “Snowy Bank of Lake Trasimenco” by the Spanish artist Jaime Morera Galicia (1854-1927), born in Leida. 100°C is demonstrated again by Wick’s impressive photograph of water vapor in equilibrium with boiling water in the kettle (Figure 4). An extremely high temperature, 108°C , is demonstrated by the sun in the astounding artwork “Creator’s Dance” painted around 1985 by De Es Schwertberger, born in Gresten, Lower Austria, in 1942 (Figure 5).

Finally, the Zeroth Law of Thermodynamics. Why is this law so important? Imagine you want to determine whether two bodies have the same temperature. What one would do now a day is measure with a thermometer the temperature of each body. If the readings are identical, it indicates that the two bodies have the same temperature.

However, this was not evident about 250 years ago until James Clerk Maxwell, a British Physicist, around 1871, asserted experimentally the above phenomena. He then proceeded to state a law, which subsequently was named the Zeroth Law of Thermodynamics by the British Mathematician Ralph H. Fowler. This law is commonly stated as: “Two bodies, each in thermal equilibrium with a third body, are in thermal equilibrium with each other”. The artwork “The Break in the Clouds” (1941) of Rene Magritte (1898-1967), a Belgian, one of the most important surrealist artists, may be used to demonstrate the Zeroth Law in terms of temperature readings, namely if $T_1=T_3$ and $T_2=T_3$, then $T_1=T_2$ (Figure 6). It is interesting to note that long after the First, Second and Third Laws of Thermodynamics were recognized and named, it was realized that there exists still another law. Because it’s basic character it has been designated the Zeroth Law, which accelerated the “birth” and development of the science of thermometry.

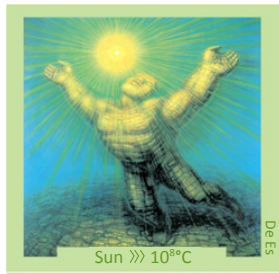


Figure 5: High temperature.

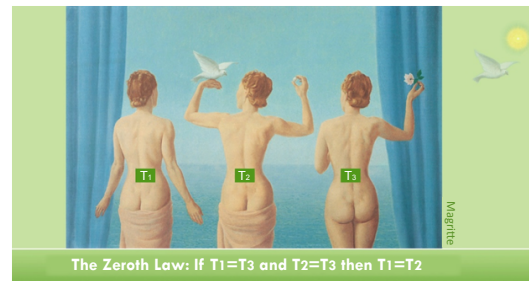


Figure 6: Thermal equilibrium.