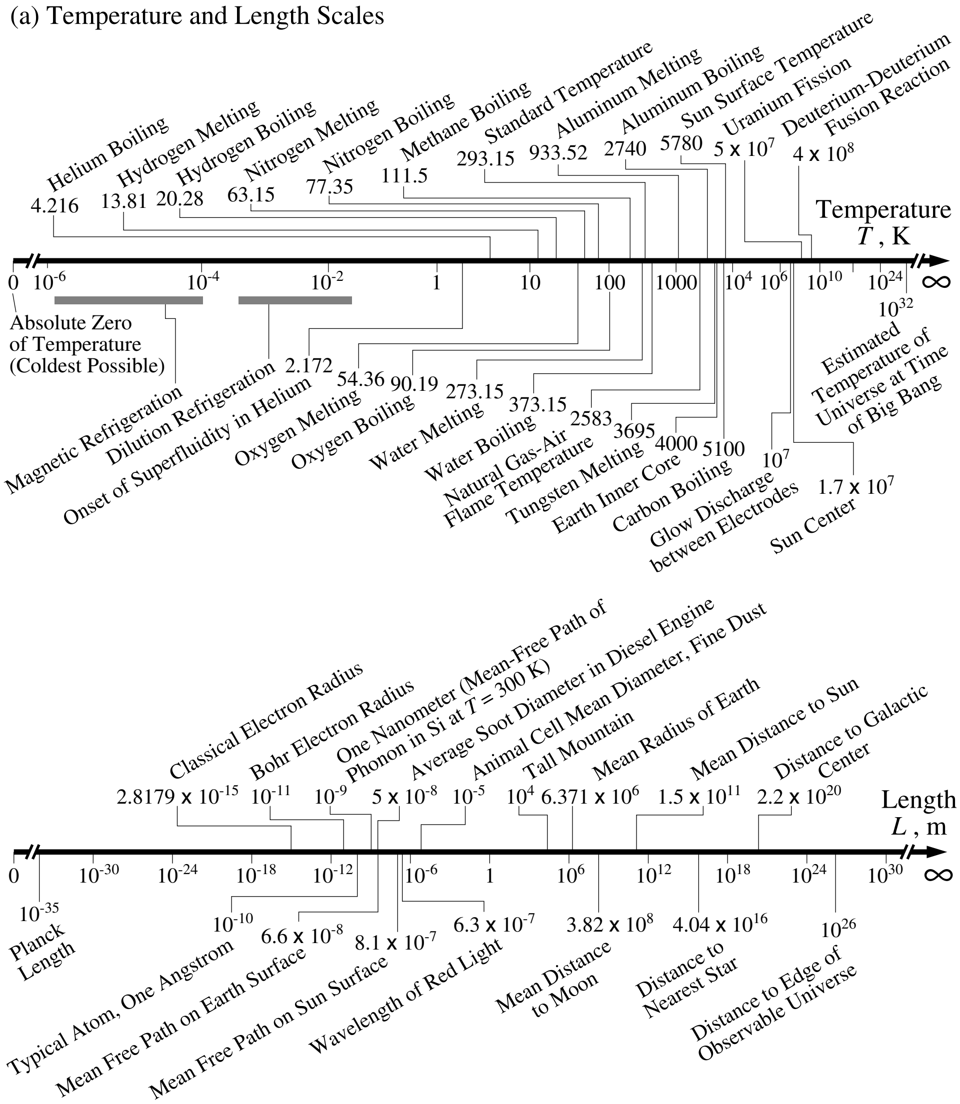

Figure 1.1(a) Range of temperature and length scales encountered in heat transfer analysis.

(A) *Temperature, Length, Time, and Mass Scales*

In order to allow for a broad introduction to the range of phenomena and scales involved in heat transfer applications, Figure 1.1 gives examples of the temperature T [Figure 1.1(a)], length L [Figure 1.1(a)], time t [Figure 1.1(b)], and mass M [Figure 1.1(b)] scales that are encountered.

At the temperature of absolute zero, the entropy may become zero (as in a perfect crystalline structure), i.e., the highest structural order. The lowest temperature possible is $T = 0$ K (or $T = -273.15$°C), the absolute zero in Kelvin scale. Helium has the lowest boiling temperature ($T = 4.216$ K) among the elements and compounds. The absolute zero is not expected to be reached, but very low temperatures, of the order of $T = 10^{-3}$ K, are achieved by the dilution refrigeration technique [1,25]. Yet lower temperatures, of the order $T = 10^{-5}$ K, are achieved by the adiabatic demagnetization technique. In this method, a paramagnetic salt is first exposed to a magnetic field, thus causing a molecular order.

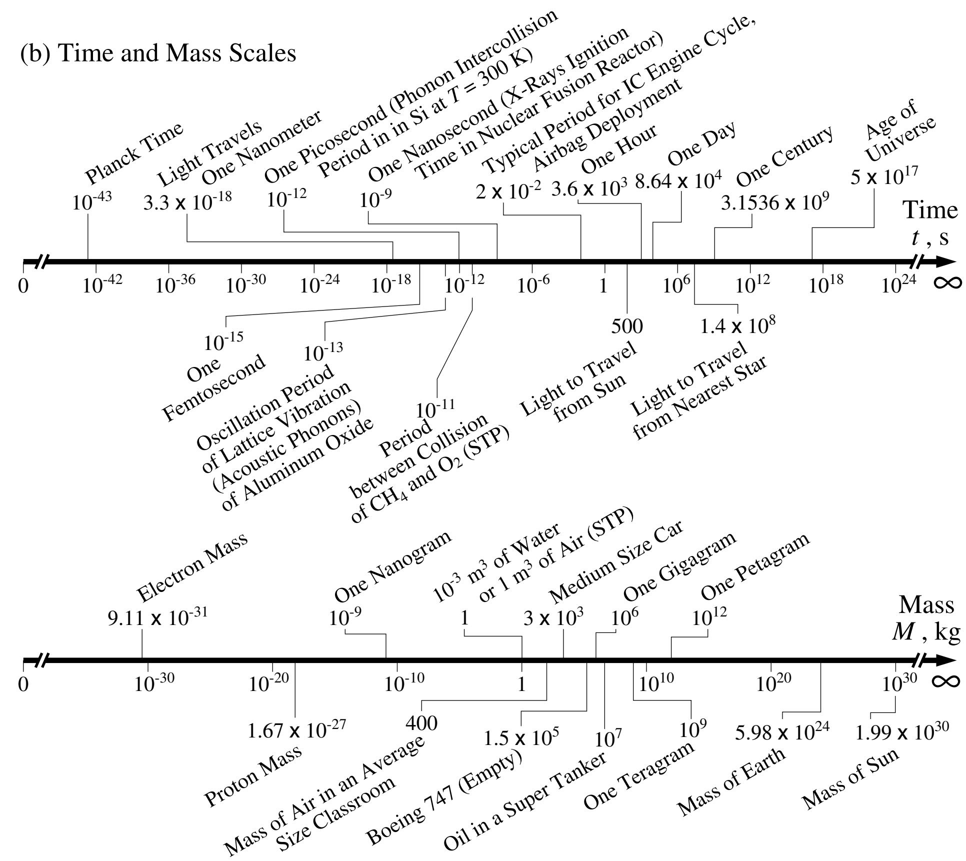

Figure 1.1(Continued)(b) Range of time and mass scales encountered in heat transfer analysis.

When the magnetic field is removed, this causes a disorder and heat is absorbed (while the paramagnetic salt is at a very low temperature).

For detection of very small temperature differences, the semiconductors are used. The electrical resistivity ρ_e of semiconductors has a rather unusually large dependence on temperature, especially at low temperatures. Then temperature variations as small as one-millionth of one ℃ can be measured.

The upper bound for temperature is not known. One of the highest temperatures predicted is that based on a theory of formation of the universe. This will be discussed shortly, but the theory predicts a temperature of nearly $T = 10^{32}$ K, at the very beginning of the creation of the universe [8]. In a fusion reactor, temperatures of the order of $T = 10^8$ K are required for a continuous reaction. Thermal plasmas with temperatures in the range of $T = 10^4$ to 10^6 K are used for materials processing. The prefix cryo- is used in reference to very cold and pyro- in reference to very hot (as in cryogenics and pyrogenics referring to physical phenomena at very low and very high temperatures).

The smallest length with a physical significance is the Planck length, 1.616×10^{-35} m (obtained by combining the Newton constant of gravity $G_{\rm N}$, Planck constant $h_{\rm P}$, and speed of light in vacuum c_o), while the radius of the earth is $R = 6.371 \times 10^6$ m, and the mean distance between the earth and the sun is $L = 1.5 \times 10^{11}$ m. The mean-free path of the air (mostly nitrogen and oxygen) at standard temperature ($T = 20$℃) and pressure