1.3 TEMPERATURE SCALES

To develop a temperature scale one needs to find reproducible thermal equilibrium situations. Historically, the freezing and boiling points of water at the atmospheric pressure were selected as highly reproducible equilibrium states of matter. The two common scales of temperature, the Celsius or centigrade (C) and Fahrenheit (F), use these reference states.

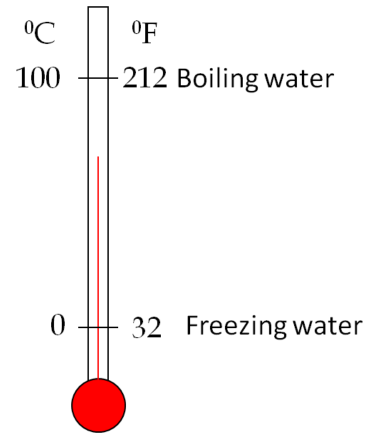

Figure 1.6: The freezing point and boiling point of water are assigned 0° and 100° in Celsius scale and 32° and 212° in Fahrenheit scales.

In the **Celsius scale**, we assign a value of zero degree to the freezing point of water and a value of 100 degrees to the boiling point of water. In **Fahrenheit**, the freezing point is assigned 32 degrees and the boiling point 212 degrees.

There are 180 degrees in Fahrenheit scale between the freezing and boiling points of water while there are only 100 degrees in the Celsius scale. Therefore, each degree change in the Celsius scale is equal to $\frac{180}{100}$ or $\frac{9}{5}$ degrees change in the Fahrenheit scale. If a particular temperature reads C degrees in Celsius and F degrees in Fahrenheit, then their relation will be:

$$\boxed{F = \frac{9}{5}\,C + 32.} \tag{1.1}$$

Scientists use another temperature scale, called the Absolute or Kelvin scale, which is based on the fundamental laws of thermodynamics. A reading in Kelvin scale to be denoted in this book by the capital letter T is related to the Celsius scale as follows.

$$\boxed{T = C + 273.15.} \tag{1.2}$$

In nature we find a wide range of temperature as shown in Fig. 1.7. the temperature of the universe as seen in the background radiation is approximately 2.7 K and ¿ 10 MK inside stars. In laboratories physicists have been able to push the temperatures to as low as 100 pK in a piece of rhodium metal and as high as 1 GK in quark-gluon plasma.

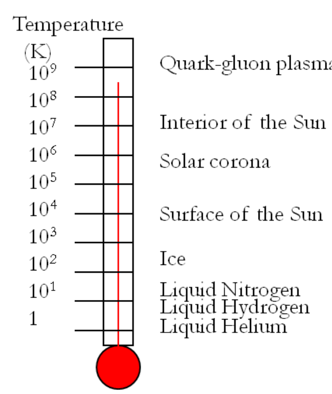

Figure 1.7: Temperature range in nature.

Example 1.3.1. Temperature Scales. Suppose the normal temperature of your body is 98°F. After jogging a mile, you find that your temperature has gone up to 99°F. (a) What is your normal body temperature in Celsius and Kelvin scales? (b) By how much has your temperature gone up in Celsius and Kelvin scales?

Solution. (a) Finding the equivalent reading in Celsius scale requires a direct application of the formula relating Celsius and Fahrenheit given above.

$$F = \frac{9}{5}C + 32 \Longrightarrow C = \frac{5}{9}(F - 32) = 36.7°\text{C}$$

The reading T in Kelvin scale is obtained by simply adding 273.15 to the Celsius reading.

$$T = 36.7 + 273.15 = 308.9 \text{ K}$$

(b) From the relation between the Celsius and Fahrenheit

$$F = \frac{9}{5}C + 32$$

we see that the rise in Fahrenheit is $\frac{9}{5}$ times the rise in Celsius. Note the adjustment of 32°F for 0°C would not appear in the difference in temperature readings.

$$\begin{aligned} \Delta F &= \frac{9}{5}\Delta C \\ \Longrightarrow \Delta C &= \frac{5}{9}\Delta F = \frac{5}{9} \times 1 = 0.56^\circ\text{C}. \end{aligned}$$

The rise in Kelvin ΔT is same as the rise in Celsius. Therefore,

$$\Delta T = \Delta C = 0.56^\circ\text{C} = 0.56 \text{ K}.$$