

# Temperature Scales and their Inventors

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and

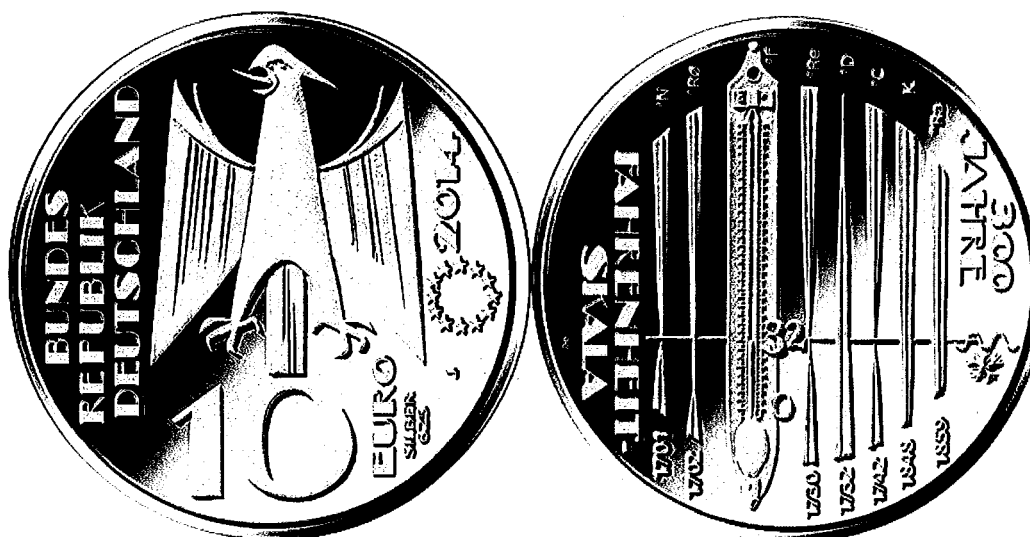
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Eight temperature scales have found significant scientific or everyday use in the last 300 years. Although some of them are no longer used and are hardly remembered, all have an interesting history of development.

The eight scales are featured together on a commemorative silver coin (KM332) minted by Germany in 2014, marking the 300th anniversary of the Fahrenheit temperature scale (Figure 1). The reverse side of the coin graphically displays each scale and the associated year of its development (except 1714, which is omitted, since it is the year implied for the Fahrenheit scale by the coin's theme and date on the obverse). In this article the scales and their inventors will be discussed in the same chronological order in which they are found on the coin and their descriptions will be illustrated by various postal items related to them.



**Figure 1.** The eight temperature scales shown on the reverse of the coin: degree Newton ( $^{\circ}\text{N}$ ), degree Rømer ( $^{\circ}\text{Rø}$ ), degree Fahrenheit ( $^{\circ}\text{F}$ ), degree Réaumur ( $^{\circ}\text{Ré}$ ), degree Delisle ( $^{\circ}\text{D}$ ), degree Celsius ( $^{\circ}\text{C}$ ), kelvin (K), and degree Rankine ( $^{\circ}\text{Ra}$ ).

## Newton, Isaac

Isaac Newton (1642-1727)<sup>1</sup> was an English physicist and mathematician who made many important scientific discoveries. In the area of temperature measurement, he considered how thermometers could provide standard, reproducible values, and adopted Christian Huygens' idea of a temperature scale defined by two fixed values. Huygens (1629–1695) had suggested the freezing and boiling points of water as the two reference values. Newton kept the freezing point as his lower fixed value, but suggested that the upper reference be equal to the human body temperature. He then divided the range between the two reference values into 12 equal segments (so the body temperature would be equal to 12 degrees on this scale). Newton extrapolated the scale to warmer temperatures and found that its value for the boiling point of water would be about 33 degrees. He put forth these ideas in **1701**. It is interesting to note that Newton's scale corresponds closely to the modern degree Celsius temperature scale in the following way: if we multiply Newton's reference values by 3, then we retain 0° (3 x 0) for the freezing point of water (0°C), and obtain 36° (3 x 12) for the normal human body temperature (actually 37 °C) and 99° (3 x 33) for the boiling point of water (actually 100 °C).

To honor his scientific work, Newton's name was given to the SI (Système International, or International System of Units) unit of force. SI is the international standard for units in modern science as well as everyday use. One newton is the force needed to increase the speed of a mass of one kilogram by one meter per second in a period of one second. It is therefore equal to one kilogram meter per second squared.

There are numerous postal items featuring Newton. Some of them refer to Newton's telescope or other optical pursuits. Others note Newton's Law of Universal Gravitation. The authors know of only two that include his Second Law of Motion, force = mass times acceleration ( $F = ma$ ). That deceptively simple equation is so important in science that Newton's name was given to the SI unit of force.

A stamped envelope from Romania printed in 2003 [1] mentions Newton and gives the " $F = ma$ " formula in the cachet.

A second illustrative item is a stamp issued by Germany in 1993 (Scott No. 1771, Michel No. 1646) [2]. It includes the impulse version of Newton's Second Law: impulse (force times change in time) equals the change in momentum (mass times velocity). The authors maintain a detailed list of all known philatelic items honoring Newton and it can be found at: <http://rammb.cira.colostate.edu/dev/hillger/precursor.htm#newton>.

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<sup>1</sup> Isaac Newton was born on 25 December 1642 on the Julian calendar. On the Gregorian calendar, Newton's birth occurred 4 January 1643.

CLUBUL FILATELIC "BARICADA" ZIARUL "ZIUA" SALONUL CAMPIONILOR 2003

ISAC NEWTON  $F = ma$   
 MARIE CURIE  $Ra; Po$   
 ALBERT EINSTEIN  $E = mc^2$   
 NIELS BOHR  $E = -\frac{Rch}{n}$   
 E. RUTHERFORD  $N(\alpha, p) O$   
 W. HEISENBERG  $\Delta E \Delta t = h$   
 ENRICO FERMI  $X \xrightarrow{\beta, \gamma} Y$

MARI PERSONALITĂȚI ALE ȘTIINȚEI UNIVERSALE  
 BUCUREȘTI 21 - 23 martie 2003

POSTA ROMÂNĂ 150  
 3000 L  
 ROMÂNIA

BERBE CURIEI (1859-1906) MARIE CURIEI (1867-1934) 1923 PREMIUL NOBEL FIZICĂ  
 400 754 CLUJ NAPOCA  
 A.H. BECQUEREL (1852-1908)

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Codul Localitatea

ROV  
 Sa stare veselă

[1]



[2]

### Roemer, Olaus (Rømer, Ole)

Olaus Roemer (1644-1710) was a Danish astronomer. In the early 1690s, he began to measure and record the air temperature to account for its effects on his astronomical work, and starting in 1702 he constructed his own spirit (alcohol) thermometers. He also devised a temperature scale to use with them, in which the freezing point of water was 7.5 degrees and its boiling point was 60 degrees. In this scale, 0 °Rø would have been equal to the modern -22.5 °C. Measurements of around 0 °Rø made in early 1709 (very cold for Denmark), support many other historical records of the severity of that winter in Europe.

None of the postal items showing Roemer are related to his temperatures scale. The earliest Roemer item was issued by Denmark (Scott No. 293, Michel No. 285) in 1944 for the 300th anniversary of his birth [3]. Other postal items that the authors have found for Roemer are available at: <http://rammb.cira.colostate.edu/dev/hillger/precursor.htm#roemer>.



[3]

### **Fahrenheit, Daniel Gabriel**

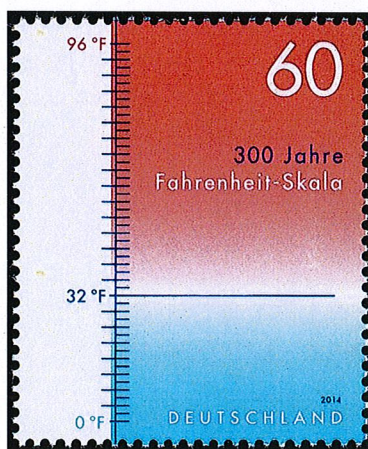
In 1708 Daniel Fahrenheit (1686-1736), a young scientist eager to learn about Roemer's work, visited him in Copenhagen. Roemer showed him a modified scale, with the upper fixed point of  $22.5^{\circ}\text{R}\ddot{o}$  being the human body temperature (which he supposed constant), while the lower fixed point of  $7.5^{\circ}\text{R}\ddot{o}$  was unchanged from his earlier work. Fahrenheit, no fan of “inconvenient and awkward fractions” according to his letters, modified Roemer's scale. He divided each degree into four parts, so that the lower fixed point became  $30^{\circ}$  ( $4 \times 7.5$ ) and the upper fixed point became  $90^{\circ}$  ( $4 \times 22.5$ ). On this scale the boiling point of water is  $205^{\circ}$ . He used this modified Roemer scale until around 1717 when he decided to make small changes to the fixed points, so that the freezing point of water became  $32^{\circ}\text{F}$  and the human body temperature became  $96^{\circ}\text{F}$ . On this changed scale the boiling point of water was  $212^{\circ}\text{F}$ . Fahrenheit made this change for a very practical reason. With fixed points of  $32^{\circ}$  and  $96^{\circ}$ , there were 64 degrees between the two, and a scale with 64 divisions could easily be drawn by successive subdivisions of the full interval into two equal parts, since 64 is a power of two. This procedure is not possible if the fixed points are  $30^{\circ}$  and  $90^{\circ}$ . Later, when he discovered that the human body temperature is not constant (*i.e.*, young people tend to have a higher body temperature than their elders, and people with fever have increased body temperature), Fahrenheit simply redefined the upper fixed point as being equal to the boiling point of water, with the value of  $212^{\circ}\text{F}$ .

Fahrenheit is generally credited as the first person to construct commercially available reliable thermometers. At first he followed common practice and used alcohol in his thermometers, starting in around 1709. However, he was able to develop a method to purify mercury, and so in

1714 he became the first person to take advantage of its properties for use in thermometers. Another of his improvements to thermometer design was the introduction of cylindrical bulbs to replace spherical ones. Fahrenheit seems to have been a good businessman, and his detailed technique for making thermometers remained a trade secret for some time. Perhaps the commercial availability and quality of his thermometers explain why his temperature scale became so widely accepted, while many other scales retreated to obscurity.

The United States is now the only major country that still clings to the degree Fahrenheit temperature scale. The vast majority of the rest of the world uses the degree Celsius temperature scale, which is the accepted international standard for everyday temperature measurement and for scientific work.

Among the philatelic items issued that depict or mention Fahrenheit, Germany issued a stamp in 2014, with the same theme as the coin already mentioned. The stamp (Scott No. 2808, Michel No. 3109) [4] shows the degree Fahrenheit scale and celebrates its 300th anniversary. Related material can be found at: <http://rammb.cira.colostate.edu/dev/hillger/precursor.htm#fahrenheit>.



[4]

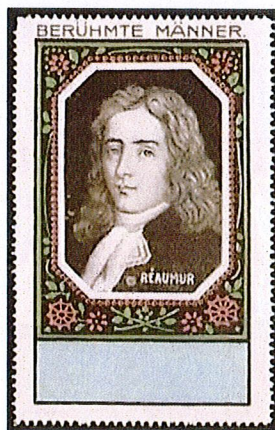
### de Réaumur, René-Antoine Ferchault

René de Réaumur (1683-1757) was a French naturalist and member of the French Academy of Sciences who worked in many different areas. His principal interest was the study of insects. One of his projects related the growth of insects to temperature. Possibly as a result of that work, he became interested in temperature measurement. He constructed a thermometer in which the freezing point of alcohol was zero degrees and the mark for each degree above zero was determined by one one-thousandth of the volume of the alcohol in the thermometer bulb and tube below the zero degree mark. Under this definition the boiling point of the alcohol he was using was 80 degrees. By 1730 such a thermometer came to be known as the Réaumur alcohol thermometer, and the 0-80 degree scale as the degree Réaumur temperature scale (°Ré, °Re, °R).

After Réaumur's time, researchers used different liquids in their thermometers, and some defined 80 degrees as the boiling point of water rather than alcohol. This resulted in much confusion. This is possibly why Antoine de Lavoisier (1743–1794) found, in 1776, that some temperature values provided by a Réaumur thermometer were not in agreement with those of more recent instruments. Mercury eventually became the standard liquid used in thermometers (except for extreme cold temperature measurements since mercury freezes at approximately  $-39\text{ }^{\circ}\text{C}$  but alcohol in an alcohol thermometer freezes at  $-115\text{ }^{\circ}\text{C}$ ). Mercury thermometers can use the 0-80 degree scale, but by their design they are not Réaumur thermometers. They are given that name simply because of the scale.

In his work in Ecuador in the years 1735-1744, Charles de La Condamine (1701–1774) was one of the first to use the Réaumur thermometer. The Réaumur scale became popular in France, Germany, Russia, and other parts of Europe. It eventually fell into general disuse, but lives on in some parts of Switzerland and Italy in the measurement of milk temperature for cheese production.

No postage stamps have been issued for Réaumur; only a cinderella (year unknown) from West Germany is known to the authors [5]. Other postal items related to Réaumur can be found at: <http://rammb.cira.colostate.edu/dev/hillger/precursor.htm#reaumur>.



[5]

### **Delisle, Joseph-Nicolas**

Joseph Delisle (1688-1768) was a French astronomer who is mainly remembered for the Delisle temperature scale. In 1732 he built a mercury thermometer for which he chose the boiling point of water as the fixed zero degree point. For lower temperatures, he defined a scale based on the contraction of mercury (in hundred-thousandths), with higher values at lower temperatures (*i.e.*, an inverted scale, in which higher numbers represent "increasing cold"). Delisle's original scale needed 2400 or 2700 graduations to handle the cold winters of St. Petersburg where he lived. In 1738 the German professor of medicine and anatomy Josias Weitbrecht (1702-1747) introduced

a modification to Delisle's scale: Weitbrecht kept 0 °D as the boiling point of water but assigned a value of 150 °D as its freezing point. Though the scale was still inverted, the resulting smaller sizes of the temperature values were more in line with other temperature scales of the time. The Delisle temperature scale was used in Russia for almost 100 years.

No postal items are known to show Delisle; he is found only on the German coin already presented.

## **Celsius, Anders**

Anders Celsius (1701-1744) was a Swedish astronomer and mathematician who worked in thermometry. Celsius was probably aware of Newton's temperature scale and built on it in 1742 by proposing a 100 degree scale between the freezing point of water (100° in his original scale) and the boiling point of water (0° in his original scale). He published this proposal in a paper entitled "Observations on two persistent degrees on a thermometer". It is not known what led him to associate the higher value with the colder fixed point, and vice versa. Perhaps he wanted to introduce more originality into his work, or perhaps he was influenced by the Royal Society's temperature scale (used until about 1725), in which the "0" was "extreme hot" and "90" was "extreme cold".

In any case, Celsius' proposed scale was intuitively backwards and was inverted soon after his death so that 0° was the lower fixed point and 100° the upper fixed point. In this way the modern Celsius scale was born. It was accepted as a standard, first in Sweden and France, and then across the globe. Temperature values measured in this scale were originally referred to as degrees "centigrade" ("centi" referring to one hundred, and "grade" referring to degrees). However, in 1948, Celsius' name became the official temperature unit, when the Ninth General Conference of Weights and Measures declared that "degrees centigrade" should thereafter be referred to as "degree Celsius"<sup>2</sup>. The Celsius scale is the accepted international standard over the vast majority of the globe.

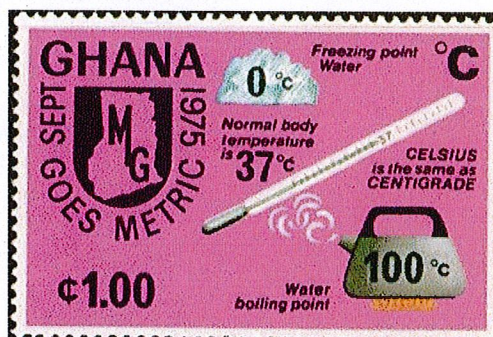
Of the postal items honoring Celsius, one issued by Nevis in 2000 (Scott No. 1185k, Michel No. 1458) [6] mentions that Celsius "invents centigrade thermometer", using the outmoded name for the temperature scale. On another postage stamp [7] issued by Ghana in 1976 (Scott No. 573, No. Michel 633) for their conversion to the metric system, the name Celsius is equated to "centigrade" for practical purposes. Other postal items specifically mentioning Celsius can be found at: <http://rammb.cira.colostate.edu/dev/hillger/precursor.htm#celsius>. On several other postal items that display temperatures, only the symbol °C for degree Celsius is shown (for those items, see: <http://rammb.cira.colostate.edu/dev/hillger/thermometers.htm#temperature>).

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<sup>2</sup> The term *degree centigrade* was a synonym for this unit until 1948. From three names ("degree centigrade," "centesimal degree," and "degree Celsius") proposed to denote the degree of temperature, the latter was chosen.



[6]



[7]

### Thomson, William (Lord Kelvin)

William Thomson (1824-1907) was a Scottish physicist and engineer. He made a wide range of scientific contributions, but is best remembered as the originator of the kelvin<sup>3</sup> temperature scale.

In **1848** Thomson proposed a temperature scale based on the fundamental laws of thermodynamics. In the construction of his scale, he took into account the fact that there had to exist a point at which no “caloric” (heat) could be transferred. That point became the zero degree point in his scale. This absolute cold (now known as absolute zero) was an idea that had been discussed as far back as Robert Boyle (1627–1691), in his 1665 work *New Experiments and Observations touching Cold*. Pierre-Simon Laplace (1749–1827) and Lavoisier also considered the concept during their work on heat and calorimetry in the 1780s, as did John Dalton (1766–1844) in his 1808 work *A New System of Chemical Philosophy*.

Thomson was given the title First Baron Kelvin in 1892, and came to be known as Lord Kelvin, just as his temperature scale became widely known as the kelvin scale, with temperatures measured in degrees kelvin. In modern scientific usage (as already mentioned, the Système International, or SI, is the scientific standard) these temperatures are referred to as kelvins (no word “degree”), with the symbol K (no degree symbol)<sup>4</sup>. 0 K (absolute zero) is equal to -273.16 °C on the Celsius scale and -459.67 °F on the degree Fahrenheit scale.

In honor of his scientific work, Kelvin's name was given to the SI unit of thermodynamic temperature. The kelvin scale is an absolute temperature scale. A change in temperature of one kelvin is the same as a change of one degree Celsius.

<sup>3</sup> Note that the kelvin temperature scale, when spelled out, is not capitalized, to distinguish the unit name from the person Kelvin. The symbol K, however, is capitalized.

<sup>4</sup> This unit was called the *degree Kelvin*, symbol °K, until 1967, when the name *kelvin*, symbol K, replaced it. The old forms, as well as the symbol “deg,” were officially declared obsolete in 1980.

A small number of postal items show Lord Kelvin. Among them is a stamp issued by Guinea-Bissau in 1983 (Scott No. 540, Michel No. 702) [8]. Kelvin's name is also included on a stamp from Cuba (Scott No. 2173, Michel No. 2268) [9] that lists the seven base SI units. For other postal items for Kelvin, see: <http://rammb.cira.colostate.edu/dev/hillger/precursor.htm#kelvin>.



[8]



[9]

### Rankine, William John Macquorn

William Rankine (1820-1872) was a Scottish engineer who had a wide interest in many branches of science and mathematics. In **1859** he proposed a new temperature scale which had its zero point at absolute zero, and with one Rankine degree equal in size to one Fahrenheit degree. The Rankine scale is also an absolute temperature scale, and so is the same as the kelvin scale, except that the latter uses Celsius degrees rather than Fahrenheit degrees. As already noted, for scientific work in which the absolute temperature is required, the kelvin scale is now the international standard. The Rankine scale was used in the past in some engineering applications in places such as the United States where Fahrenheit temperatures were common, but to the authors' knowledge it is no longer used anywhere.

No postal items are known to show Rankine; he is found only on the German coin already presented.

### Additional online information

Checklists of postal items for many scientists, including the eight men discussed above, are available at <http://rammb.cira.colostate.edu/dev/hillger/precursor.htm>. The authors would like to hear from anyone who knows of additional postal items that may have been missed.