Temperature: metamorphoses[1] in manual and computer calculations

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Abstract. The article describes how it is possible and necessary to conduct calculations on a computer using the physical quantity of temperature, and how one can carry out calculations without temperature at all, considering it a derived, and not a basic unit of measurement.

Key words: thermal conductivity, temperature, Newton's second law, ideal gas equation, computer calculations with units of measure.

The discussion will be based on a couple of calculated examples.

Problem 1. It is necessary to find the thermal conductivity of red brick material at the temperature of 20 ° C. In order to do this, we launch any Internet search engine, enter the desired query, and go, for example, to a site with the address https://myslide.ru/documents_7/2fc09c287fbee035e4c243ef3d7c85bb/img31.jpg that shows the graph in Figure 1.

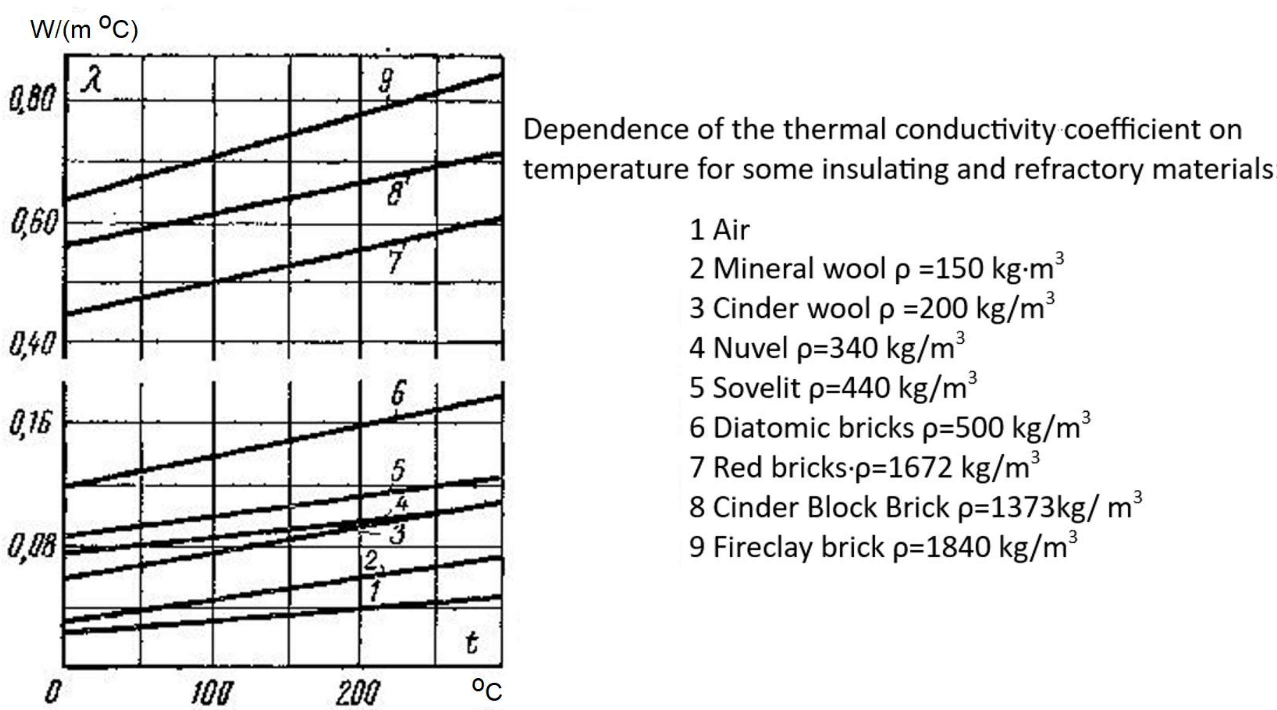

Fig. 1. Graphs showing the variations of the thermal conductivity with temperature for some materials

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[1] The Metamorphoses (from Ancient Greek: μεταμορφώσεις: "Transformations") is also a Latin narrative poem from 8 CE by the Roman poet Publius Ovidius Naso, known in English as Ovid. The poem chronicles the history of the world from its creation to the deification of Julius Caesar in a mythico-historical framework. In the last book, Phytagoras, the great mathematician, teaches among other things about the changeability of everything.

This graph was created quite a long time ago, as evidenced by, firstly, its fuzzy image, secondly, by the temperature unit °C used for the thermal conductivity, and thirdly, by the the word "coefficient" applied to the name of this transport property of some building materials (see comments below). However, this information can be used to calculate (estimate) the thermal conductivity of a red brick at 20 °C (see Figure 2) with simple calculations (linear interpolation) in the physical and mathematical package SMath[2].

Remark on the unit of temperature for the thermal conductivity units and on the thermal conductivity itself

During a visit to the US National Institute of Standards and Technology (www.nist.org), the authors of this article received a handbook on the thermophysical properties of water and steam as a gift from their American colleagues, which contained two tables with the following headings:

Table U-6. Isobaric Heat Capacity of Water and Steam ($\mathrm{Btu \cdot lb_m^{-1} \cdot °R^{-1}}$)

Table U-9. Thermal Conductivity of Water and Steam ($\mathrm{Btu \cdot h^{-1} \cdot ft^{-1} \cdot °F^{-1}}$)

The letter U in the title means that these are tables in US units. The given handbook also contained corresponding tables with European units for the heat capacity (($\mathrm{J \cdot kg^{-1} \cdot K^{-1}}$) and for the thermal conductivity ($\mathrm{W \cdot m^{-1} \cdot K^{-1}}$). Tables with these units were in the Russian reference book [1], which the authors of this article presented to colleagues from NIST (in return!).

The American unit of the specific isobaric heat capacity (Table U-6) contains the "correct transoceanic" degree Rankine °R, i.e. the American analogue of the European kelvin, K = 1.8 °R. However, in the American unit for the thermal conductivity (Table U-9), instead of the Rankine degree, it turned out to be the Fahrenheit degree °F. When the authors asked their colleagues at NIST if this was a typo, they replied that it would be more likely to change the US constitution than to teach American engineers, the users of such tables, to have the correct degrees of Rankine instead of the wrong degrees of Fahrenheit in the unit of thermal conductivity. Then the authors suggested to their American colleagues that they change (Table U-6) the degrees of Rankine to degrees Fahrenheit also in units of the specific isobaric heat capacity, for consistency. The authors were told that this would be completely illiterate and would shock thermodynamic specialists now! In the USSR, by the way, degrees Celsius were also used in the unit of thermal conductivity (see Figure 1), while considering them equal to degrees Kelvin by default, but then they switched to kelvins. The transition from the term "degree Kelvin" to simply kelvin was also not so easy [2], and we will return to this point later. There is also no uniformity of terminology. Many thermophysicists believe that thermal conductivity is a physical phenomenon with a unit of measure called the thermal conductivity coefficient (see Figure 1). Metrologists, with their standards, insist that the coefficient is something dimensionless (friction coefficient, for example), and thermal conductivity is both a physical phenomenon (transport property) and a dimensional unit of measurement, and the term "coefficient" is inappropriate here. By the way, the coefficient of friction is also not a completely dimensionless quantity, i.e. it is the ratio of the force applied to the body to move it to the weight of the body, Newtons to Newtons, which are usually reduced to dimensionless. They also reduce the meters in the unit of thermal conductivity, as we will mention below.

The dependence of the thermal conductivity of the red brick material with the temperature is linear. Figure 2 shows how, by searching for the root of a system of two linear equations, using the built-in function roots, the numerical values of the coefficients a and b of the dependence $\lambda = a + b\,T$ are determined and the thermal

[2] This program can be downloaded in a couple of minutes from the site www.smath.com and installed free of charge in the basic version on your computer. The extended licensed version of the package contains the functions of the WaterSteamPro and CoolProp packages, which return the thermophysical properties of heat carriers and working fluids of thermal power engineering—the same thermal conductivity, for example.

conductivity value at 20 °C is calculated, displayed with a red dot on the blue line. Everything is simple and clear, but...

$T_1 := 0 \quad \lambda_1 := 0.54 \qquad T_2 := 300 \quad \lambda_2 := 0.61$

$$\begin{bmatrix} a \\ b \end{bmatrix} := \mathrm{roots}\left(\begin{bmatrix} \lambda_1 = a + b \cdot T_1 \\ \lambda_2 = a + b \cdot T_2 \end{bmatrix}, \begin{bmatrix} a \\ b \end{bmatrix}\right) = \begin{bmatrix} 0.5400 \\ 0.0002333 \end{bmatrix}$$

$T := 20$

$\lambda(T) := a + b \cdot T = 0.5447$

$TT := [0, 1 .. 300] \qquad \lambda T := \lambda(TT)$

$$C := \begin{cases} \mathrm{augment}(TT, \lambda T) \\ \mathrm{augment}(T, \lambda(T), \text{"."}, 5, \text{"red"}) \\ \mathrm{augment}(T, \lambda(T), \mathrm{num2str}(\lambda(T), \text{"n4"}), 5, \text{"red"}) \end{cases}$$

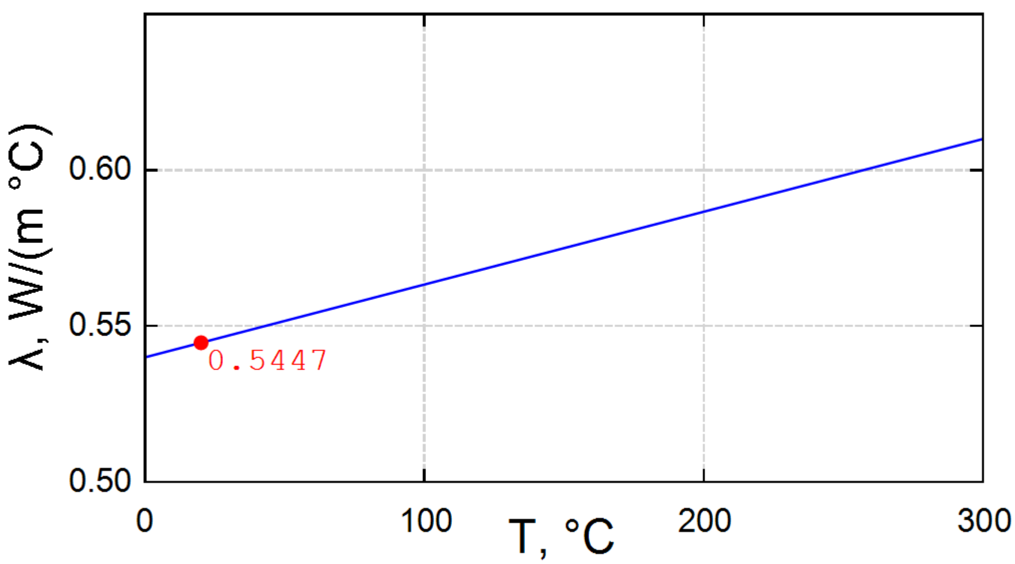

Fig. 2. Finding the dependence of the thermal conductivity on temperature without using units

The calculation in Figure 2 produced a so-called empirical formula, that requires some tricks in order to be used in modern computer environments that include units of measurement (the modern standard of calculations), as shown in Figure 3.

$$T := 20\ {}^{\circ}\mathrm{C}$$

$$\boxed{\lambda := a + b \cdot T = \blacksquare\ \blacksquare}$$

Units don't match.

$$\lambda := \left(a + b \cdot \left(\frac{T}{\mathrm{K}} - 273.15 \right) \right) \frac{\mathrm{W}}{\mathrm{m\ K}} = 54.4667\ \frac{\mathrm{W\ cm}}{\mathrm{m}^{2}\ \mathrm{K}}$$

$$T := 68\ {}^{\circ}\mathrm{F}$$

$$\lambda := \left(a + b \cdot \left(\frac{T}{\mathrm{K}} - 273.15 \right) \right) \frac{\mathrm{W}}{\mathrm{m\ K}} = 0.3147\ \frac{\mathrm{BTU}}{\mathrm{hr\ ft}\ \Delta{}^{\circ}\mathrm{F}}$$

Fig. 3. Working with an empirical formula

The first call of the empirical formula gave an error message, i.e. the coefficient *a* is dimensionless, while the product of *b* by *T* has dimension. In order for the empirical expression $\lambda = a + b\ T$ to "capture" the temperature and to return the answer with the unit of the thermal conductivity, it is necessary to deprive the original variable *T* of the temperature dimension (T/K) [3] and then to reduce (to translate) it to the Celsius scale (T/K – 273.15) i.e. to get the value 20, not 293.15. It is also required to add to the answer the base unit of thermal conductivity $\mathrm{W \cdot m^{-1} \cdot K^{-1}}$ [3]. This is a rule for working with empirical formulas in SMath. Based on Figure 3, the final unit of thermal conductivity is not simplified to the expression $\mathrm{W \cdot m^{-1} \cdot K^{-1}}$, which allows us to clearly see the Fourier law in it: if we take a wall with an area of a square meter and a thickness of one centimeter, then thermal energy with a power of 54.45 Watts will pass through it with a temperature difference on the sides of the wall of one degree Celsius, I beg your pardon, one kelvin. The third call to the empirical formula for the thermal conductivity of the red brick material is carried out using "overseas" units of measurement.

Figure 2 shows interpolation without using units. This is what has usually been done and is being done when working with programming languages and spreadsheets. Such an outdated manner of calculation, fraught with errors, many, alas, are transferred to modern calculation programs, in SMath, for example. If someone works with units of measurement, then the calculation of the thermal conductivity of the red brick material can be carried out as shown in Figure 4, where the coefficients *a* and *b* of the empirical dependence have become dimensional. The formulas by which these coefficients are calculated were obtained as a result of the symbolic (analytical) solution of the system of equations shown in Figure 2 in the first argument of the roots function. An empirical formula, as the reader knows, is a formula obtained experimentally (empiric!). As a result, very often such formulas include not just physical quantities, but physical quantities tied to given units of measurement. The approach shown in Figure 3 allows us to bypass this limitation and to work with any units of temperature and thermal conductivity. By the way, there are also pseudo-empirical formulas (from the authors), which are described in [3].

[3] The blue color and bold font next to the variable K means that it is a unit of measurement and not a user variable.

$$T_1 := 0\ °C \qquad \lambda_1 := 0.54\ \frac{W}{m\ \Delta°C}$$

$$T_2 := 300\ °C \qquad \lambda_2 := 61\ \frac{W\ cm}{m^2\ K}$$

$$a := \frac{\lambda_2 \cdot T_1 - \lambda_1 \cdot T_2}{T_1 - T_2} = 0.4763\ \frac{W}{m\ \Delta°C}$$

$$b := \frac{\lambda_1 - \lambda_2}{T_1 - T_2} = 23.3333\ \frac{mW\ cm}{m^2\ K^2}$$

$$T := 20\ °C$$

$$\lambda(T) := a + b \cdot T = 54.4667\ \frac{W\ cm}{m^2\ K}$$

Fig. 4. Finding the dependence of thermal conductivity on temperature with units of measurement

Returning to the problem of degrees Rankine and degrees Fahrenheit, touched upon above, it can be noted that in the SMath and Mathcad environments (the American analogue of SMath) they made a compromise, i.e. they introduced the temperature units Δ°C (see Figure 4) and Δ°F (Figure 3), numerically equal to kelvin and degree Rankine, respectively.

In the calculations in Figures 3 and 4 some variables named *T* were entered not just as numerical values, but as numerical values with temperature units attached to them. And what do the variables T, T_1 and T_2 store in the heart of the computer? In order to answer this question, we will consider the solution of another simple problem, not a heat transfer problem, a thermodynamic one. These two disciplines are united by the field of knowledge "Theoretical foundations of heat engineering". By the way, the authors of this article work at a department with this name.

Problem 2. Oxygen is stored in a 40-liter cylinder under an overpressure of 150 bar. The barometer shows atmospheric pressure of 745 mm Hg. The gas temperature is 10°C. Determine the mass of oxygen in the cylinder, based on the ideal gas equation relating pressure p, temperature T and specific molar volume v.

Figure *5* shows how data is entered with the conversion of dimensions to SI base units. Then, through simple calculations, the solution to the problem is found, i.e. 8.2 kilograms of oxygen are stored in the cylinder. The weight of the cylinder will decrease by approximately this value if oxygen is released from it (by the way, the degree of filling of propane-butane liquefied gas cylinders is often controlled by installing the cylinder on weight balances).

$$V := 40\ \mathrm{L} = 0.04\ \mathrm{m}^3$$

$$M_{O2} := 32\ \frac{\mathrm{g}}{\mathrm{mol}} = 0.032\ \frac{\mathrm{kg}}{\mathrm{mol}}$$

$$p_a := 745\ \mathrm{mmHg} = 99325\ \mathrm{Pa}$$

$$p_{op} := 150\ \mathrm{bar} = 1.5 \cdot 10^7\ \mathrm{Pa}$$

$$p := p_a + p_{op} = 1.5099 \cdot 10^7\ \mathrm{Pa}$$

$$T := 10\ ^\circ\mathrm{C} = 2354.2\frac{\mathrm{J}}{\mathrm{mol}}$$

$$p \cdot v = T$$

$$v := \frac{T}{p} = 0.0001559\ \frac{\mathrm{m}^3}{\mathrm{mol}}$$

$$M := \frac{V}{v} \cdot M_{O2} = 8.2095\ \mathrm{kg}$$

Fig. 5. Determination of the mass of oxygen in a cylinder

In the last sentence, an inaccuracy was deliberately made: weight is measured in units of force, and not units of mass (not kilograms). Weight (gravity) and mass are often confused. These two quantities are related to Newton's second law, which will be discussed below.

Let us imagine that a reader, opening a physics textbook, sees a formula like: $m\ a = k\ F$, with an explanation that this is a mathematical notation of Newton's second law, where m is mass (mass), a is acceleration (acceleration), F is force (force), and k is the universal force constant. Of course, the reader will be surprised and say that there should not be any constant k in this formula. But he/she will be objected in the sense that the constant k serves to convert the force expressed in kilogram-force into newtons, and that the acceleration of free fall is hidden in the constant k. And they will explain also that people have long been accustomed to expressing force in kilograms-force, and not in some incomprehensible Newtons. That is why this formula contains the value k, which is called the universal force constant (a force constant). Force can be expressed in other common units—in dynes, in pounds-force, and so on. (see their full list, for example, here https://www.calc.ru/Sila/?ysclid=lbxb3a3osr936832601). But all this must first be converted into kilograms-forces, and only then insert the resulting value into the formula of Newton's second law $m\ a = k\ F$.[4]

[4] By the way this is formulation is closer to the original Newton formulation, that was not written in mathematical terms (formula) but only by words (translated from Latin from the original 1687 edition of the Principia Mathematica). LAW II: “The alteration of motion is ever proportional to the motive force impressed; and is made in the direction of the right line in which that force is impressed” see:

But if we open a textbook on classical thermodynamics—one of the sections of physics, then we will see, in reality, a similar formula $p\ v = R\ T$ "burdened" with the constant R with an explanation that p is the pressure (pressure), v is the specific molar volume (volume), T is the temperature (temperature), and R is the universal gas constant, which serves to convert kilograms-forces, sorry, degrees Kelvin, sorry again, kelvins into ... the correct temperature units.

So, in the problem of the mass of oxygen in a balloon, the correct ideal gas equation $p\ v = T$ was used, not burdened by the conversion coefficient R. The entered temperature of 10 °C is stored in the computer's memory not in kelvins, but in joules divided by a mole. The rest of the initial values are stored in a computer with the usual SI units: not in liters, but in cubic meters, not in grams per mole (the molar mass of diatomic oxygen), but in kilograms per mole, not in bars or mm of mercury, but in pascals. But the temperature, we emphasize again, is stored in units of energy divided by units of the amount of matter.

The fact that the temperature expressed in kelvins and other temperature degrees is a "dummy" quantity has long been known. Here is what it is possible to read in the fifth volume of the Landau and Lifshitz course in theoretical physics (Nauka publishing house, 1960 and 1981): «*...The conversion factor between ergs and degrees is called the Boltzmann constant* $k = 1.38\cdot10^{-16}$ *erg/deg. We will agree further in all formulas to mean temperature measured in energy units. For the transition in numerical calculations to a temperature measured in degrees, it is enough to simply replace T by kT. The constant use of the multiplier k, the only purpose of which is to recall the conventional units of temperature measurement, would only clutter up the formulas.*». (https://scask.ru/c_book_t_phis5.php?id=11&ysclid=lbwkftyvnb53383477)

Figure 6 shows how, in SMath, the entered temperature (twenty degrees Celsius) is converted not to ergs, but to joules using the built-in constant, i.e. the Boltzmann constant k. The resulting numerical value was too small. It is very difficult to work with it with manual calculations. That is why they introduced some normalizing coefficients (the universal gas constant and the Boltzmann constant), which allow us to switch to the "normal" temperature scale with nominal degrees. The computer, on the other hand, quite calmly operates with any values, which allows us to return the temperature to its lawful unit of measurement.

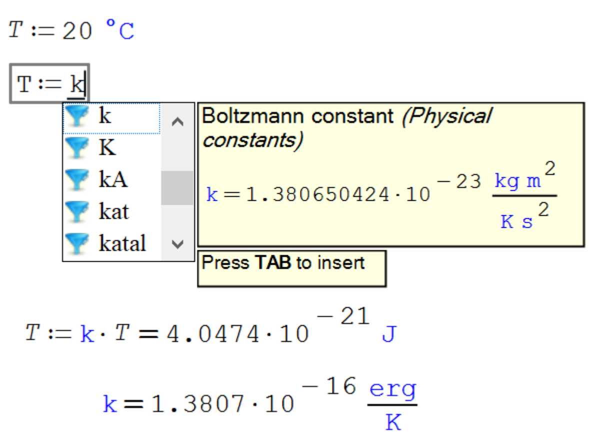

Fig. 6. Boltzmann constant in SMath

Historically, the empirical concept of temperature first appeared with different nominal degrees and scales (Fahrenheit—1724, Reaumur—1730, Celsius—1742, etc.), but only much later, after a whole century (1834 – 1874, Maxwell, Boltzmann, Clapeyron, Clausius, Mendeleev, etc.) a theoretical equation of state of an ideal gas with temperature was derived, which had to be adjusted to "degrees" by introducing the concept of

https://www.physics.utoronto.ca/~jharlow/teaching/everyday06/reading01.htm#:~:text=In%20an%20exact%20original%201792,which%20that%20force%20is%20impressed.

"universal gas constant"[5]. Here lies the mystery of why temperature has become not just a separate physical quantity, but the main physical quantity in the SI. And it should be an auxiliary quantity, which is what we are trying to show in this article. This is indirectly evidenced by the fact that until 1968 the kelvin was officially called the degree of Kelvin. And degrees in those days were universally expelled from metrology [2] and transferred to the category of auxiliary quantities. Recall angular degrees, degrees of hardness, degrees of Engler (liquid viscosity), degrees of water hardness, alcohol degrees, etc. Yes, the degree of Kelvin was renamed to kelvin. But this is like how the "metrological house" did not carry out a major cleaning, but simply ... swept the garbage under the carpet. By the way, the degree of Rankine (an overseas analogue of the degree of Kelvin, kelvin) has remained the degree of Rankine: there are no rankins (temperature units) in metrology and are not expected.

The mentioned course of theoretical physics was written at a time when there were no computer tools for working with physical quantities and it was necessary to do recalculations manually or on slide rules. Then came electronic calculators, "non-physical" programming languages and spreadsheets. In our time, we repeat, we can return to the origins, to the fact that from the standpoint of metrology, temperature is not a separate physical quantity, but energy divided by the amount of substance with a conversion coefficient called the universal gas constant (or Boltzmann constant—see Figure .6). For the same purposes (the convenience of manual conversions), decibels, pH values of solutions, and other sub-units of measurement, including logarithms, were introduced a long time ago. In modern computer calculations, they are not needed. Temperature and other degrees, decibels, etc. needed only to display the results of the calculation.

Figure 7 shows the units with which some physical quantities will be consistently stored, whose current units include kelvins. In this case, the Boltzmann constant will be numerically equal to the reciprocal of the Avogadro number, and the entropy will finally become dimensionless.

Thermal·Conductivity $\qquad \dfrac{\mathrm{W\ m}}{\mathrm{m}^2\ \dfrac{\mathrm{J}}{\mathrm{mol}}} = 1\ \dfrac{\mathrm{mol}}{\mathrm{m\ s}}$

Thermal·Resistance $\qquad \dfrac{\dfrac{\mathrm{J}}{\mathrm{mol}}}{\mathrm{W}} = 1\ \dfrac{\mathrm{s}}{\mathrm{mol}}$

Specific·Heat·Capacity $\qquad \dfrac{\mathrm{J}}{\mathrm{kg}\ \dfrac{\mathrm{J}}{\mathrm{mol}}} = 1\ \dfrac{\mathrm{mol}}{\mathrm{kg}}$

Molar·Heat·Capacity $\qquad \dfrac{\mathrm{J}}{\mathrm{mol}\ \dfrac{\mathrm{J}}{\mathrm{mol}}} = 1$

Specific·Molar·Entropy $\qquad \dfrac{\mathrm{J}}{\mathrm{mol}\ \dfrac{\mathrm{J}}{\mathrm{mol}}} = 1$

Fig. 7. True units of some physical quantities

The dispute about the degrees of temperature in the unit of the thermal conductivity (see the beginning of the article) is resolved radically, i.e. there are no temperature units there, but only moles, meters and seconds—see Figure 8.

[5] In fact, the experimental Boyle's law, Charles's law, Gay-Lussac's law and Avogadro's law were generalized by the ideal gas law. Somehow the introduction of the Universal Gas Constant, R is also due to these empirical ancestors of the theoretical ideal gas law.

$$\lambda := 54.47 \frac{W\ cm}{m^2\ K} = 6.5508 \frac{mol\ cm}{m^2\ s}$$

Fig. 8. Basic unit of the thermal conductivity

By the way, in the unit of the thermal diffusivity (thermal conductivity divided by the specific mass isobaric heat capacity and density), however strange it may seem, there are no units of temperature, but only square meters divided by seconds. The introduction of the concept and of the unit of thermal diffusivity was an attempt to circumvent the difficulties associated with an empirical approach to temperature.

Another example to support the possibility to remove temperature form computer calculation comes from the first principle of thermodynamics relating energy to work and heat (joules, units in fact) in a process engineering application. To determine the duty of a heat exchanger (Q) between a cold and hot fluid (like a house water boiler), it is necessary to write an enthalpic balance:

Q=Hout-Hin (cold side)=Hin-Hout (Hot side)

Knowing the mass specific enthalpy h (J/kg) of the streams entering and exiting the heat exchanger (cold and hot sides), there is no need to know the streams temperature nor the heat capacities (and latent heats if there is a change of phase), but just the specific enthalpy since H=h (specific enthalpy) x w (mass flowrate).

Are the temperatures still strictly necessary to determine the area of the heat exchanger? Q=U (Overall heat transfer coefficient) A (heat exchanger Area) DT lmtd (DT mean logarithmic).

The removal from computer calculations of the unit of temperature as one of the seven basic units of the SI may not occur immediately, but with a certain transitional period. Figure 8 shows SMath settings window. In the last line of this window, you can put a "tick" and go to the three-term, and not the four-term formula of the ideal gas equation. After that, the temperature entered in any degrees and on any scales will first be converted to kelvins, and then, by multiplying by the universal gas constant, converted into a numerical value with a composite unit of joule divided by mole.

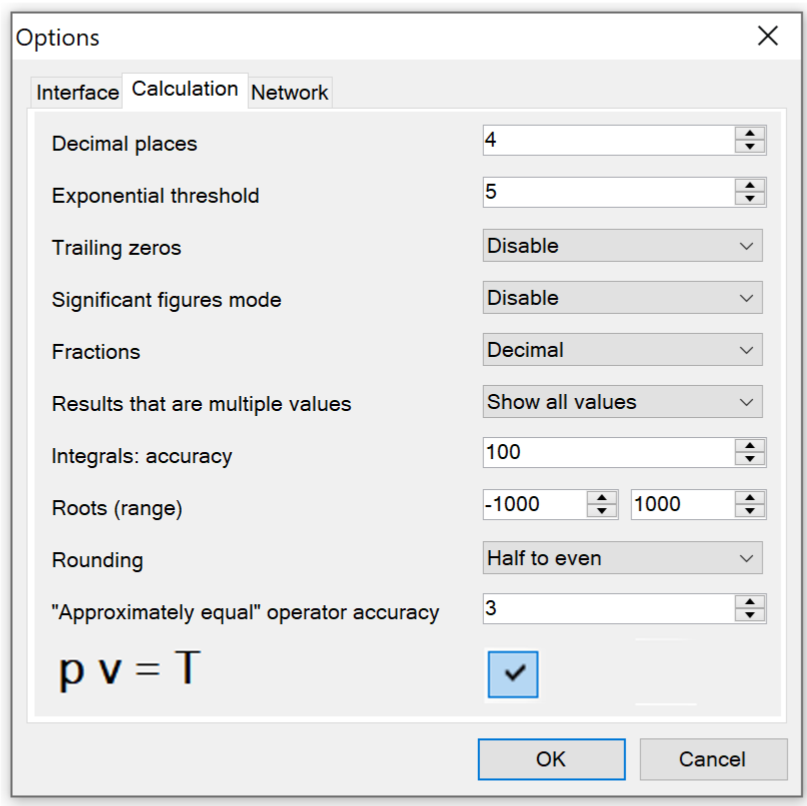

Fig. 9. Switch in SMath to the correct temperature units (in the correct ideal gas equation)

Figure 10 shows a dialog box for entering temperature units, in which (after ticking the checkbox, see Figure 9) the correct temperature unit will appear in the first place.

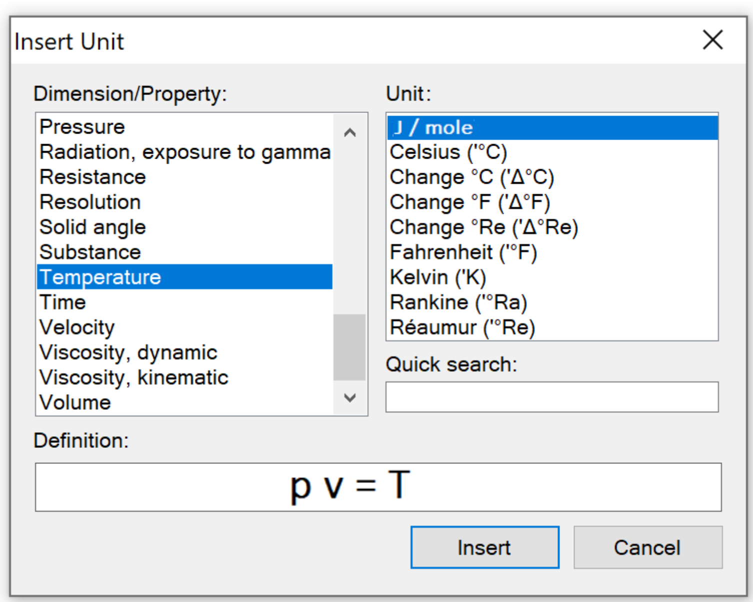

Fig. 10. Dialog box for entering temperature units

Funny metrological afterword

The dispute about the units of measurement, described at the beginning of the article, continued at the Denver airport, from where the American colleagues escorted the authors of this article home, or rather, to New York for a transfer. Near the capital of the state of Colorado is the city of Boulder with a branch of NIST, where the described exchanges took place. An American colleague noted that only international (European) units of measurement are used at all US airports. If American units leak somewhere, it will be a scandal, an emergency. This is due, in particular, to the famous sad case (see https://en.wikipedia.org/wiki/Gimli_Glider), when a passenger Boeing-767 with a hundred passengers had an emergency landing at a former Royal Canadian Air Force base in Gimli, Manitoba, that had been converted to a racetrack. The accident was due to the fact that the required amount of fuel was miscalculated because the units for the density of the aviation kerosene were mixed up between American and European. An American colleague jokingly added that if we would notice pounds-feet-Fahrenheit at this airport, then he would have offer a bottle of good bourbon. The authors began to turn their heads and immediately noticed a sign with feet and inches on the elevated passage between the airport buildings, under which our car was passing. This marking is placed on all bridges under which vehicles pass. The American colleague said that he had lost the bet, and that this was again due to the fact that it is easier to "change the US constitution" than to force American drivers to operate in meters and kilometers, rather than feet and miles. By the way, on the highways of North America it is easy to find out where someone is, i.e. in the USA, Canada or Mexico. One has only to look at the road markings and clarify what is used, i.e. miles or kilometers. By the way, also on the border between Germany and German-speaking Switzerland, it is easy to determine somebody location. If someone walks or eats along a Straße, then this is Germany, while if he/she goes along a Strasse, then Switzerland.

Readers will laugh, but the story about standards in reference books and about a bottle of alcohol "on a bet" was repeated by the first author of the article also in Germany. A German colleague gave the author his handbook on the thermophysical properties of water and water vapor and said that if the handbook would contain at least one comma instead of a dot as a separator between the integer and fractional parts of numbers, then he would have offered a bottle of schnapps! The fact is that at that time Germany was switching to this international standard, and in reference books there was confusion with "punctuation marks" in numbers. Approximately the same as observed with degrees Celsius-Fahrenheit and degrees Kelvin-Rankine when working with thermal conductivity. In Russian version of this article, you can also notice such a hodgepodge in the numerical "punctuation",i.e. in the numbers of the text it is necessary to put a comma (Russian editors with proofreaders insist on this), while in the figures there are points between the integer and fractional parts of the numbers. But SMath is also good in that it gives the user the choice of using a dot or a comma in decimal numbers. By the way, this is also the way the Excel spreadsheet is arranged, which many people use to solve engineering, scientific and technical problems. However, the spreadsheets are not adapted to work with units of measurement, which is the cause of many errors in calculations associated with incorrect conversion of units of measurement and adding "meters to kilograms". In SMath, we emphasize again, such errors are excluded.

Conclusions

Modern computer calculation programs make it possible to finally complete the long historical process of transition to the correct temperature units. At the same time, it remains possible to work with the usual temperature degrees and scales when entering and displaying temperature values and other quantities containing temperature units.

The question is, why do this!? And then, to finally put things in order in the system of units. Remove, for example, such a discrepancy when physicists measure temperature in electron volts, and everyone else in degrees Kelvin.

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