Homework 15.

Temperature. Ideal gas laws.

We know very well that a hot object has higher temperature than a cold one. So, the higher temperature of *something* the more hot that *something* is. But it is much more difficult to explain what the temperature *is*. What is the physical meaning of this parameter? We know that all of the objects around us consist of small particles which move chaotically all the time. Temperature of the object is proportional to the average kinetic energy of the particles (atoms of molecules) of the object.

If we are cooling down, say, a glass of water, molecules of water are slowing down and losing their kinetic energy (they transfer it to another object – an ice cube, for example). Since there is minimal possible kinetic energy – 0.0J (all the particles stop) we can conclude that there is the minimal possible temperature. In the real world there is not possible to stop the particles completely and cool the object down to absolute zero temperature. There are four major temperature scales.

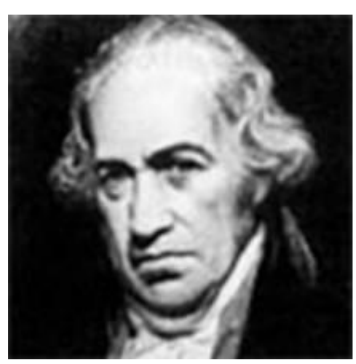
1. Fahrenheit temperature scale

2. Celsius temperature scale

3. Kelvin temperature scale

4. Rankin temperature scale

The property of certain objects to expand or contract depending on temperature was known since ancient times. But first person who produced thermometer with reliable operation and reproducible readings was Daniel Gabriel Fahrenheit – German physicist and engineer. In 1724 he introduced new temperature scale which is now known as Fahrenheit scale.



Daniel Gabriel Fahrenheit (1686-1736)

Fahrenheit used mercury as a working substance in his thermometer and, what is most important, he suggested the way to calibrate the device. For calibration he used three points. One was the temperature of the mix contained water, ice and special salt - ammonium chloride. An interesting property of this mixture (which is called *frigorific* mixture) is that after being prepared it reaches equilibrium at the temperature which is almost independent on the initial temperatures of the mixture components. Fahrenheit ascribed to this temperature the magnitude of 0 degrees. The other two points were temperatures of water mixed with ice (32^oF) and the temperature of a human body ($96\ ^oF$). 2

Anders Celsius (1701-1744)

Zero point of the Celsius scale, named after Swedish astronomer Anders Celsius (1701-1744) corresponds to the temperature of melting ice, temperature of hundred degrees corresponds to the temperature of boiling water. To recalculate Fahrenheit temperature into the Celsius temperature we have:
1. Take the temperature in Fahrenheit degrees and subtract 32.

2. Multiply the result by 5 and divide by 9 – you have the Celsius temperature.

The Kelvin scale is the scale used in physics. One degree of the Kelvin scale is equal to 1 Celsius degree, but 0^oC corresponds to 273 degrees at the Kelvin scale (we write 273K). And the last one, Rankin scale has same degree as Fahrenheit scale, but zero point corresponds to absolute zero (Kelvin zero).

There are 3 simple laws which establish the connection between temperature, pressure and volume of ideal gas. Speaking about “ideal gas” we mean the gas consisting of the particles (atoms or molecules) which do not interact (repel or attract) with each other. This is not true for most of the real gases, but if the temperature is high enough the effect of the interaction is small and real gas behaves like the ideal one. So, the laws are:

1. Boyle -Mariotte law:

Pressure x Volume = does not change, or PV=const

This means that if the temperature of the gas remains unchanged decreasing the gas volume we will increase the gas pressure and vice versa.

2. Charle’s law:

$\frac{Volume}{Temperature}$ does not change, or $\frac{V}{T} = const$

If the pressure of the gas remains unchanged, as the temperature of the gas increases the volume of the gas increases as well. This law describes thermal expansion of gas at the constant pressure.

3. Gay-Lussac’s law

$\frac{Pressure}{Temperature}$ does not change, or $\frac{P}{T} = const$

If the volume of the gas remains unchanged, increasing the gas temperature we will increase the gas pressure and vice versa.

Important note: pay special attention to the units. **Kelvin scale should be used to express temperature**(!).

All the gas laws can be unified in one:

$$\frac{P \cdot V}{T} = const$$

Problems:

1. Is there a temperature which is the same on both Fahrenheit and Celsius scales? – (This problem is more about math than physics).

2. What is the temperature of a human body in according to the Kelvin scale?

3. A cylinder is filled with gas. The pressure inside is 10 000Pa, the temperature is 20C. We increase the temperature to 100C. What happens to the pressure inside the cylinder? Calculate the new pressure.

4. A cylinder with a piston is filled with gas and the pressure inside is 100 000Pa. The temperature of the cylinder is kept constant. The pressure inside the cylinder is equal to the pressure outside the cylinder, so the piston does not move. The volume of the gas inside the cylinder is 1000 cm3. We put a 1kg stone on the piston. The piston moves down and stops, compressing the gas in the cylinder. Find the new volume of the gas if the area of the piston is 10 cm^2. (To solve this problem you have to remember what the pressure is and how we calculate it).