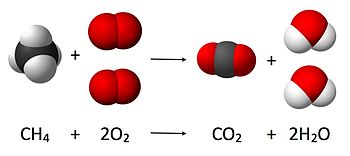
Thermodynamics

Boltzmann constant, (symbol k), a fundamental constant of physics occurring in nearly every statistical formulation of both classical and quantum physics. The constant is named after Ludwig Boltzmann, a 19th-century Austrian physicist, who substantially contributed to the foundation and development of statistical mechanics, a branch of theoretical physics. Having dimensions of energy per degree of temperature, the Boltzmann constant has a value of 1.38064852 × 10−23 joule per kelvin (K), or 1.38064852 × 10−16 erg per kelvin.

The physical significance of k is that it provides a measure of the amount of energy (i.e., heat) corresponding to the random thermal motions of the particles making up a substance. For a classical system at equilibrium at temperature T, the average energy per degree of freedom is kT/2. In the simplest example of a gas consisting of N non-interacting atoms, each atom has three translational degrees of freedom (it can move in the x-, y-, or z-directions), and so the total thermal energy of the gas is 3NkT/2.When you burn something, the mass of the products is always equivalent to the mass of the reactants. this principle is known as conservation of mass.The law of conservation of mass or principle of mass conservation states that for any system closed to all transfers of matter and energy, the mass of the system must remain constant over time, as system's mass cannot change, so quantity cannot be added nor removed. Hence, the quantity of mass is conserved over time.

The law implies that mass can neither be created nor destroyed, although it may be rearranged in space, or the entities associated with it may be changed in form. For example, in chemical reactions, the mass of the chemical components before the reaction is equal to the mass of the components after the reaction. Thus, during any chemical reaction and low-energy thermodynamic processes in an isolated system, the total mass of the reactants, or starting materials, must be equal to the mass of the products.

The concept of mass conservation is widely used in many fields such as chemistry, mechanics, and fluid dynamics. Historically, mass conservation was discovered in chemical reactions independently by Mikhail Lomonosov and later rediscovered by Antoine Lavoisier in the late 18th century. The formulation of this law was of crucial importance in the progress from alchemy to the modern natural science of chemistry.



Combustion reaction of [methane](https://en.wikipedia.org/wiki/Methane). Where 4 atoms of hydrogen, 4 atoms of oxygen and 1 of carbon are present before and after the reaction. The total mass after the reaction is the same as before the reaction.

The conservation of mass only holds approximately and is considered part of a series of assumptions coming from classical mechanics. The law has to be modified to comply with the laws of quantum mechanics and special relativity under the principle of mass-energy equivalence, which states that energy and mass form one conserved quantity. For very energetic systems the conservation of mass-only is shown not to hold, as is the case in nuclear reactions and particle-antiparticle annihilation in particle physics.

Mass is also not generally conserved in open systems. Such is the case when various forms of energy and matter are allowed into, or out of, the system. However, unless radioactivity or nuclear reactions are involved, the amount of energy escaping (or entering) such systems as heat, mechanical work, or electromagnetic radiation is usually too small to be measured as a decrease in system mass.

For systems where large gravitational fields are involved, general relativity has to be taken into account, where mass-energy conservation becomes a more complex concept, subject to different definitions, and neither mass nor energy is as strictly and simply conserved as is the case in special relativity.

Industrialization in Europe led to more powerful machines which required engines. James watt created a sophisticated steam engine.A steam engine is a heat engine that performs mechanical work using steam as its working fluid.

Steam engines are external combustion engines where the working fluid is separated from the combustion products. Non-combustion heat sources such as solar power, nuclear power or geothermal energy may be used. The ideal thermodynamic cycle used to analyze this process is called the Rankine cycle. In the cycle, water is heated and changes into steam in a boiler operating at a high pressure. When expanded using pistons or turbines mechanical work is done. The reduced-pressure steam is then exhausted to the atmosphere, or condensed and pumped back into the boiler.

In general usage, the term steam engine can refer to either complete steam plants (including boilers etc.) such as railway steam locomotives and portable engines, or may refer to the piston or turbine machinery alone, as in the beam engine and stationary steam engine. However, a more detailed look at the steam locomotive referred to the engine as only that part where the heat in the steam was turned into motion of the piston, and hence enabled separate statements for boiler efficiency and engine efficiency. Specialized devices such as steam hammers and steam pile drivers are dependent on the steam pressure supplied from a separate boiler.

The use of boiling water to produce mechanical motion goes back over 2000 years, but early devices were not practical. The Spanish inventor Jerónimo de Ayanz y Beaumont obtained a patent for a rudimentary steamf-powered water pump in 1606. In 1698 Thomas Savery patented a steam pump that used steam in direct contact with the water being pumped. Savery's steam pump used condensing steam to create a vacuum and draw water into a chamber, and then applied pressurized steam to further pump the water.

Thomas Newcomen's atmospheric engine was the first commercial true steam engine using a piston, and was used in 1712 for pumping flood water from a mine. 104 were in use by 1733. Eventually over two thousand of them were installed.

In 1781 Scottish engineer James Watt patented a steam engine that produced continuous rotary motion. Watt's ten-horsepower engines enabled a wide range of manufacturing machinery to be powered. The engines could be sited anywhere that water and coal or wood fuel could be obtained. By 1883, engines that could provide 10,000 hp had become feasible. The stationary steam engine was a key component of the Industrial Revolution, allowing factories to locate where water power was unavailable. The atmospheric engines of Newcomen and Watt were large compared to the amount of power they produced, but high-pressure steam engines were light enough to be applied to vehicles such as traction engines and railway locomotives.

Reciprocating piston type steam engines remained the dominant source of power until the early 20th century, when advances in the design of electric motors and internal combustion engines gradually resulted in the replacement of reciprocating (piston) steam engines in commercial usage, and the ascendancy of steam turbines in power generation. Considering that the great majority of worldwide electric generation is produced by turbine type steam engines, the "steam age" is continuing with energy levels far beyond those of the turn of the 19th and 20th century.

Perpetual motion is motion of bodies that continues indefinitely. A perpetual motion machine is a hypothetical machine that can do work indefinitely without an energy source. This kind of machine is impossible, as it would violate the first or second law of thermodynamics.

These laws of thermodynamics apply even at very grand scales. For example, the motions and rotations of celestial bodies such as planets may appear perpetual, but are actually subject to many processes that slowly dissipate their kinetic energy, such as solar wind, interstellar medium resistance, gravitational radiation and thermal radiation, so they will not keep moving forever.

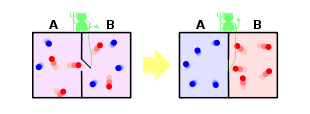
Thus, machines that extract energy from finite sources will not operate indefinitely, because they are driven by the energy stored in the source, which will eventually be exhausted. A common example is devices powered by ocean currents, whose energy is ultimately derived from the Sun, which itself will eventually burn out. Machines powered by more obscure sources have been proposed, but are subject to the same inescapable laws, and will eventually wind down.

In 2017 new states of matter, time crystals, were discovered in which on a microscopic scale the component atoms are in continual repetitive motion, thus satisfying the literal definition of "perpetual motion". However, these do not constitute perpetual motion machines in the traditional sense or violate thermodynamic laws because they are in their quantum ground state, so no energy can be extracted from them; they have "motion without energy".

In the philosophy of thermal and statistical physics, Maxwell's demon is a thought experiment created by the physicist James Clerk Maxwell in which he suggested how the second law of thermodynamics might hypothetically be violated. In the thought experiment, a demon controls a small door between two chambers of gas. As individual gas molecules approach the door, the demon quickly opens and shuts the door so that fast molecules pass into the other chamber, while slow molecules remain in the first chamber. Because faster molecules are hotter, the demon's behavior causes one chamber to warm up as the other cools, thus decreasing entropy and violating the second law of thermodynamics.

The thought experiment first appeared in a letter Maxwell wrote to Peter Guthrie Tait on 11 December 1867. It appeared again in a letter to John William Strutt in 1871, before it was presented to the public in Maxwell's 1872 book on thermodynamics titled Theory of Heat.

In his letters and books, Maxwell described the agent opening the door between the chambers as a "finite being." William Thomson (Lord Kelvin) was the first to use the word "demon" for Maxwell's concept, in the journal Nature in 1874, and implied that he intended the mediating, rather than malevolent, connotation of the word.



The second law of thermodynamics ensures (through statistical probability) that two bodies of different temperature, when brought into contact with each other and isolated from the rest of the Universe, will evolve to a thermodynamic equilibrium in which both bodies have approximately the same temperature. The second law is also expressed as the assertion that in an isolated system, entropy never decreases.

Maxwell conceived a thought experiment as a way of furthering the understanding of the second law. His description of the experiment is as follows:

... if we conceive of a being whose faculties are so sharpened that he can follow every molecule in its course, such a being, whose attributes are as essentially finite as our own, would be able to do what is impossible to us. For we have seen that molecules in a vessel full of air at uniform temperature are moving with velocities by no means uniform, though the mean velocity of any great number of them, arbitrarily selected, is almost exactly uniform. Now let us suppose that such a vessel is divided into two portions, A and B, by a division in which there is a small hole, and that a being, who can see the individual molecules, opens and closes this hole, so as to allow only the swifter molecules to pass from A to B, and only the slower molecules to pass from B to A. He will thus, without expenditure of work, raise the temperature of B and lower that of A, in contradiction to the second law of thermodynamics.

In other words, Maxwell imagines one container divided into two parts, A and B. Both parts are filled with the same gas at equal temperatures and placed next to each other. Observing the molecules on both sides, an imaginary demon guards a trapdoor between the two parts. When a faster-than-average molecule from A flies towards the trapdoor, the demon opens it, and the molecule will fly from A to B. Likewise, when a slower-than-average molecule from B flies towards the trapdoor, the demon will let it pass from B to A. The average speed of the molecules in B will have increased while in A they will have slowed down on average. Since average molecular speed corresponds to temperature, the temperature decreases in A and increases in B, contrary to the second law of thermodynamics. A heat engine operating between the thermal reservoirs A and B could extract useful work from this temperature difference.

The demon must allow molecules to pass in both directions in order to produce only a temperature difference; one-way passage only of faster-than-average molecules from A to B will cause higher temperature and pressure to develop on the B side.