# JAVA APPLET FOR THE DEMONSTRATION OF BOLTZMANN'S DISTRIBUTION

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## Abstract

In the context of the relation of entropy with the number of microstates, we developed a source code in Java, for the distribution of a definite number of quanta among the atoms of a solid.
This program can be used at the learning process in the school, by changing the variables (number of atoms and the value of energy), for the understanding of the relation between entropy and the number of microstates. The benefit of this Applet is providing interactively multiple representations (illustration, dialogue e.t.c) in the context of didactics(1).

## 1. THE FORBIDDEN AND THE SPONTANEOUS PROCESSES.

Generally speaking it is considered that the second law of thermodynamics expresses the most dynamic and general idea of Physics.
This law states that (W.Thomson-1851): Any process whose sole effect is the conversion of heat to work is impossible.
Using this law we can explain the creation of cyclones, the decay of snowmen ,the necessity for repair of the houses.
The fact that we have never seen drops of water at room temperature to transform to ice cubes, perfumes to enter spontaneously to the small nice jars, broken glasses to rejoin leading to the initial jar, our room needs reorganization quite often e.t.c
Second law can justify why heat does not flow spontaneously from cold objects to hot objects, or why heat can not be converted entirely to work (for example the heat from a stem engine is not converted 100% to the work for the motion of the piston). On the contrary, work can be converted entirely to heat, for example by rubbing our hands together.
The consequences of this are that in every process there is a loss of energy in the form of heat energy.
Even the light which is emitted from the stars as thermal radiation , has not been observed as re-emitted radiation from our eyes.
Stars die when their nuclear fuel is consumed, while the consumed fuel is not reproduced in the same quantity, so the number of produced stars is less than that of the initial ones(2) .

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The verification of the Second Law is realized also in the case of the human life ,where people are born ,grow up and finally die ,while the reverse process has never been observed.
The reverse of the above processes are allowed from the First Thermodynamic Law, which is a generalized form of the conservation of energy , but they are forbidden from The Second Thermodynamic Law.
A natural path to start understanding the Second law is by thinking the direction of flow of energy in every process.
All the different forms of energy have the tendency to be diffused, leaving the total amount of energy constant, while a certain amount of energy is appeared -inevitably - in the form of heat energy.
Cars(when their kinetic energy is reduced when we release the throttle),people
Burning the calories of chemical energy, the power stations, the air in the tires, the sound waves are all examples of the transformation of organized energy to heat.
Consequently ,another statement which express the Second law would be :energy has the tendency to flow from a point where it is concentrated , becoming dispersal.
There are certain processes where the diffusion of energy (i.e .sound waves) is quite obvious and they can not be hindered from occurring ,but there are some others where the diffusing does not happen right away.
The organized form of gravitational potential energy (suppose we keep a stone in our hands) is not diffused to the surrounding, but it has the tendency to diffuse immediately after we leave the stone(3).
This temporary forbiddance of the second law may be the reason for our existence in the world and justify the infrastructure we see.

## 2.ENTROPY-DISORDER-PROBABILITY

Another statement for the Second law is : As time passes ,for every closed system ,the entropy increases.
The word entropy was created by CLAUSIUS (Ann.Phys 1865) and means transformation, while “en” means the energy transformations taking place in thermodynamics.
In the CARNOT circle the ratio of heat is equal to the ratio of absolute temperatures and the entropy was defined by CLAUSIUS as $dS=dQ/T$.
In a reversible thermal engine (as was the one CARNOT studied), the entropy offered in the cold tank is equal to the one received by the warm tank. In real, non-reversible machines, the entropy offered in the cold tank is larger than that received by the warm tank, so the total entropy is raised.
The entropy of a system is a characteristic property of the system, and for its better understanding we have to deal with the microscopic scale.
BOLTZMANN (1870) using the molecular properties of a system invented the connection of the macroscopic meaning of entropy with the microstates of a system.
BOLTZMANN’s idea was that the macroscopic description of a system is not complete, since when the system is in a certain macro state, it is possible to be in one of many available microstates. The physical quantity that allows the counting of different microstates, which correspond to the same macro state, is the entropy.

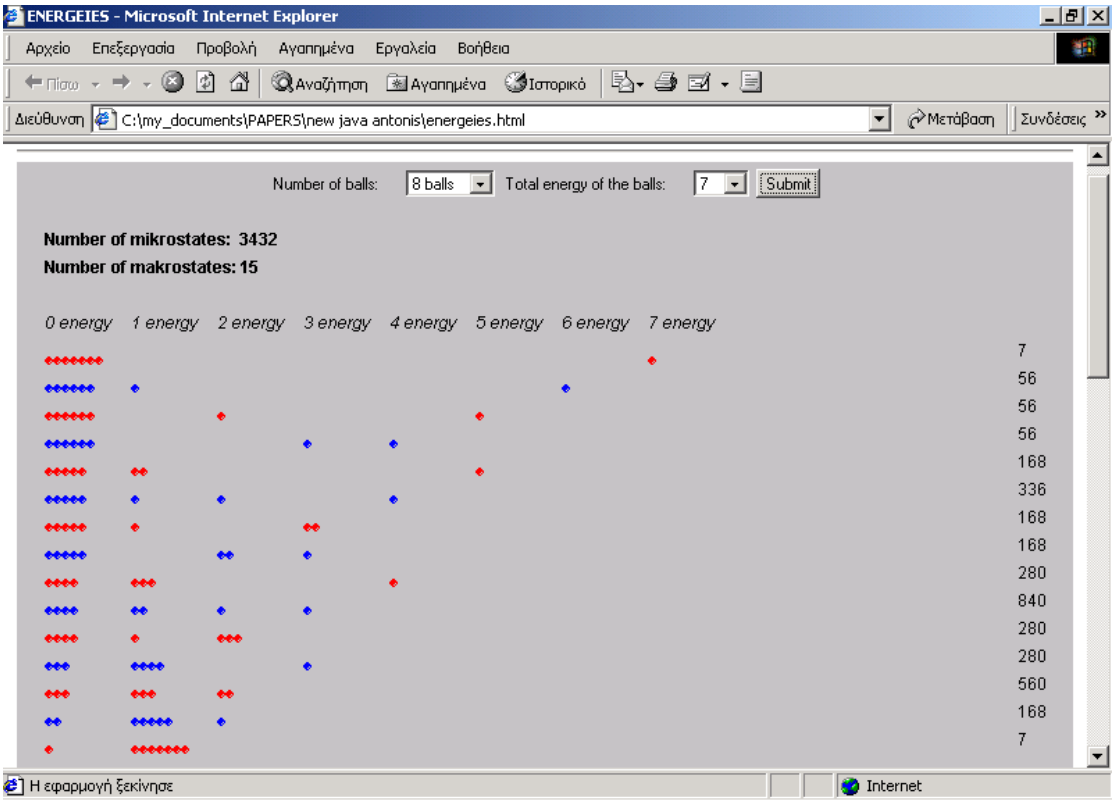
## THE PARADOX OF NON REVERSIBILITY-MOLECULAR CHAOS-THERMODYNAMIC EQUILIBRIUM

In the atomic scale , there is time reversal symmetry , resulting in time-reversal equations of motion and the exclusion of a final microscopic equilibrium state (LOSCHMIDT 1876).
On the other hand macroscopic system are not time reversal and lead at a final equilibrium state.
Therefore the problem was to find the connection between the microscopic and the macroscopic level. BOLTZMANN using the concepts of molecular chaos and incorporating the theory of probability into the Laws of Mechanics proposed the solution. The result was an equation for the time evolution of the system ,which was not time reversible ,and had its origins on the assumption of the molecular chaos.
When a warm and a cold body be in contact, there is a greater possibility that energy flows from the warmer towards the colder one, because in the warmer body there are more energy quanta.
When a stone hits the ground, a part of its organized Kinetic Energy is rearranged between the particles constituting the stone, leading the molecules in random motions (heat).
The reverse procedure, during which the random motions of the molecules will lead to an organized motion , with molecules having parallel speeds, is equivalent to the transformation of heat to work and has very small probability to occur.
When the system is in disorder, its energy is randomly allocated between the particles of the system in many more ways than when allocated in a single manner.
Entropy is connected to disorder and expresses the number of possible ways in which the energy of a system is allocated between its constituting particles.

## NUMBER OF MICROSTATES AND ENTROPY

The conservation of the energy of a system cannot explain why certain procedures can happen and others cannot.
The correlation of entropy with the number of possible microstates can offer a deeper insight on the explanation of the appearance of some processes against some others.
When we deal with a large number of particles, which behave in a random way, we use the Probability Theory, considering all the possible states of the system to have the same possibility.
The entropy (macroscopic quantity ) is connected to the microscopic level through the relationship S=K.lnW, where W is the number of symmetric (non distinguishable microstates), which leave invariant the macroscopic state of the system.
In the final state of the system the total entropy (equivalently disorder) will have reached its final value Under these considerations BOLTZMANN correlated the entropy of a system with the probability that it is led to disorder.
A simple example for the understanding of the maximization of the number of microstates in the Equilibrium State is the following:
We can consider the distribution of certain quantum of energy between the atoms of a solid body.
Due to the random interactions among the atoms, the total energy remains constant but the number of ways in which it is distributed between the atoms differ (assuming that the number of energy quanta of an atom, is independent of the number of quanta in its neighboring atoms; this is a model proposed by Einstein).
There are combinations, which occur more often and in the state of equilibrium, there is a combination, which corresponds to the greatest number of possible microstates.
Suppose that the total number of atoms is N and the number of quanta is Q. The applet accepts as input the number N of atoms (a selection from 4 to 10) as well as the number of quanta of energy Q (selection from 5 to 10). The output of the applet is

the number of macrostates and microstates and graphical representation of each macrostate along with the number of microstates corresponding to it.
An example of usage is given in the following figure:




From Mathematics it is known that there exist $\frac{(N+Q-1)!}{Q!(N-1)!}$

ways to distribute the Q quanta between the N oscillators.

,where this relation is verified in all cases but it is not used to produce the results (that is why we use the term experimental proof of the BOLTZMANN's distribution) .
Using the applet there is a strict verification of the theoretical results, when the process is handled directly from the student.

## 3.CONCLUSIONS

The advantage of the Applet is that it has the ability to be loaded and executed directly from the server at a LAN network, and also from the internet using the IP address (i.e.http://www.geocities.com/satphy). In addition to that Java programming is platform independent.
From the above it is obvious that this application can be incorporated easily in a school network or in wider educational network authorized (governed by educational authorities).

References

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