TTC – Thermodynamic Theory of Creation
(Refreshed in AD 2013)

Part 1 (of 4): Entropy

1.1 ENTROPY

To understand the meaning of Entropy[1], the first pillar of this paper, it would be useful to start with its generalized, *qualitative* definition: *it is an indicator of the state of disorder of a defined group of bodies.* **The greater is the disorder, the greater the Entropy** (*"Entropy; synonymous with disorder":* Helmholtz, 1821-1894).

We will proceed backwards until its first inception; a strictly thermodynamic origin.

To provide clarity, let us consider the following situation: a room containing a table and on the table a bottle which is sealed and filled with smoke (of unknown nature). An observer can take a photograph, as a witness, of the initial state of order: clearly defined are the bottle, the table, the smoke, which occupies a well defined volume, as well as the room (which constitutes our "universe"): system being observed plus environment.
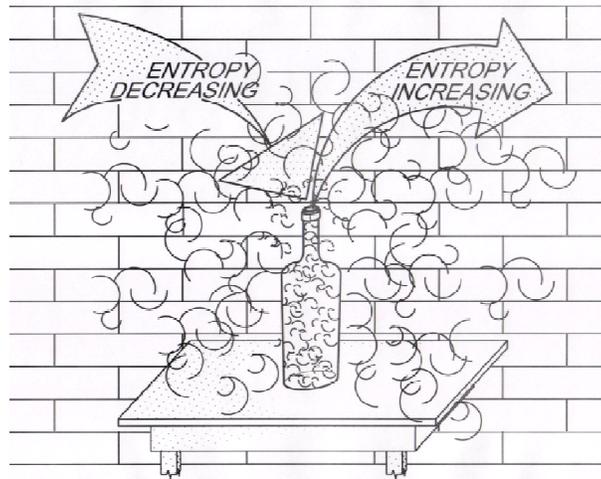

Figure 1.1 – From the point of view of Thermodynamics, the only possible spontaneous transformation is that of increasing entropy.

Opening the bottle, *Figure 1.1*, will result in diffusion of the smoke into the room. After a certain period of time (let's say a day) the observer will be able to record a state of increased disorder: the smoke has come out of the bottle.

One could imagine that after a million days the table could have disintegrated, or in any case, the interaction of this universe with others (caused, for example, by a cataclysm) would have resulted in the destruction of the table and the bottle, and finally of the room itself: the observer will take a different photograph.

Since the observations could be thought to extend over an unlimited time, the photographs, in succession, will indicate an increasing state of disorder, in other words entropy. Adopting the language of Prigogine: the transformation towards increasing entropy "produced" *positive entropy* (the difference in entropy between the final and initial states ≥ 0), while those of decreasing entropy produce *negative entropy*.

In parentheses we note that the inverse transformation (the smoke re-entering into the bottle) could not occur due to at least two reasons, each sufficient in themselves: first, the escape of smoke

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[1] **En** = *inside,* **tropien** = *direction: in the sense of side: evolution*

is an asymptotic function and its concentration tends towards perfect uniformity in volume with infinite time; second, without a concentration gradient it is not possible to have any movement of mass within the expanded smoke.

Proceeding backwards in history we observe that the concept of entropy makes its first entry in physics thanks to the work of Clausius (Germany, 1822-1888), who was searching for principles of conservation which govern thermodynamics.

<u>***The principles of conservation***</u> **(which answers the question: "what remains the same after a transformation?") represents the pillars of any scientific discipline[2].**

Curiously he falls upon a principle *of non conservation*!, and comes to define an index of state which someone defined as *anomalous* and which he called ***Entropy***.

Therefore, initially, the concept of entropy was strictly thermodynamic (the state of the system under observation depends on variables such as temperature, pressure and volume), while the observation with which we started, as stated, are macroscopic, *qualitative* generalizations.

It is understood that entropy is not an entity of conservation (except in reversible transformations which are entirely theoretical): in transformations which can be performed in practice, in which there is an interaction between the system under observation and the environment, there is an increase in entropy *after* the transformation (this allows a prediction of the direction which the transformation will take).

In *Figure 1.2* is another example: a "cold" body at temperature T_1 is placed into contact with a "warm" body at temperature T_2: the variables at play are the quantity of heat exchanged Q and the temperature T; experience tells us that the quantity of heat Q will pass from the body of higher temperature to that of lower temperature *(Clausius' postulate)* until an equilibrium temperature T_e is reached, somewhere between the two.
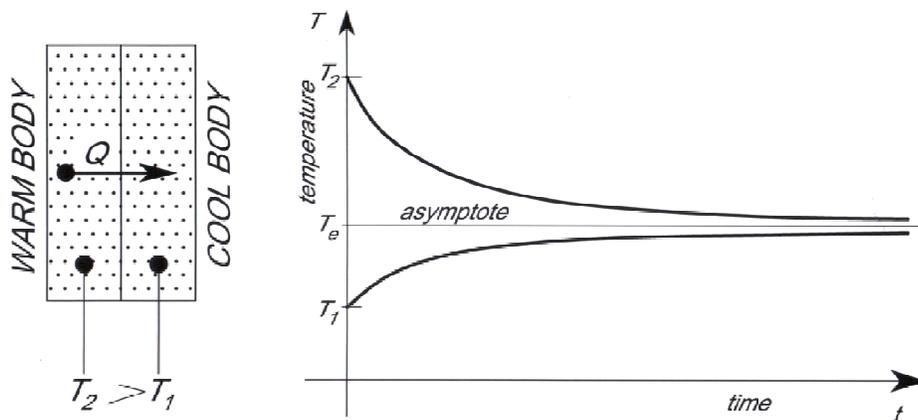

Figure 1.2 – For Clausius' Postulate

Clausius identifies that the relationship for the "quantity of heat transformed", Q, between final and initial temperatures, is

$$\frac{Q}{T_e} - \frac{Q}{T_2} > 0$$

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[2] *We are reminded, for example, amongst others, of the principle of conservation of energy, the principle of the conservation of Angular Momentum etc.*

because

$$T_e < T_2.$$

Clausius called *Entropy* the ratio $S = Q/T$.
Using current thinking we can say that the heat exchanged has performed a transformation in that

$$\Delta S > 0 .$$

1.2   A NUMERICAL APPLICATION

Now we do a simple numerical example using what we call the *Clausius Calorimeter* consisting of an adiabatic calorimeter containing water and a warm body (a cube of copper):
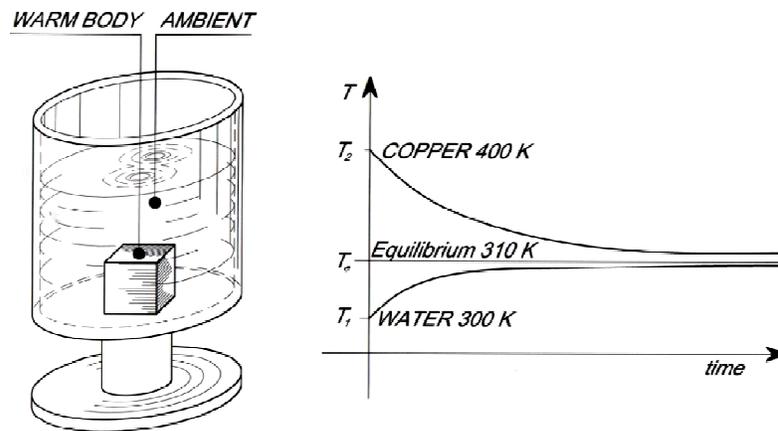
Figure 1.3 – The Clausius Calorimeter

We postulate the following conditions:

- Starting temperature of water   *300*   *K*
- Starting temperature of copper   *400*   *K*
- Equilibrium temperature   *310*   *K*
- Quantity of heat exchanged   *30*   *J.*

Since, as it is well known, the elementary variation of entropy is

$$dS = \frac{dQ}{T},$$

introducing the thermal capacity *C* (mass *m* multiplied by it's specific heat *c*) of the bodies we have

$$dQ = c \cdot m \cdot dT = C \cdot dT ,$$

and integrating for each of the two bodies we obtain:

for the copper

$$\Delta S_{Cu} = \int_{T2}^{Te} C_{Cu} \frac{dT_{Cu}}{T_{Cu}} = C_{Cu} \, ln\frac{T_e}{T_2} = C_{Cu} \cdot (-0,255),$$

for the water

$$\Delta S_{W} = \int_{T1}^{Te} C_{W} \frac{dT_{W}}{T_{W}} = C_{W} \, ln\frac{T_e}{T_1} = C_{W} \cdot (+0,033).$$

More simply we obtain the thermal capacity of each body:

$$C_{Cu} = \frac{Q}{\Delta T_{Cu}} = \frac{50}{90} = 0,\bar{5}$$

$$C_{W} = \frac{Q}{\Delta T_{W}} = \frac{50}{10} = 5 \, ,$$

and subsequently we can calculate the total variation in entropy of our closed system:

$$\Delta S = \Delta S_{Cu} + \Delta S_{W} = -0,142 + 0,165 = +0,023 \left[\frac{J}{K}\right] > 0 \qquad 1)$$

As a preview to the second law of Thermodynamics.

In the equation 1) we found two addends of opposite sign each one representing a "local" variation of entropy: it follows that even though the total entropy of the testing universe increases we can have local variations of opposite sign[3].

In fact, generally, when we have a thermal transformation some mass increase in temperature and the other decrease; the heat exchanged is equal and we can say

$$\boxed{\Delta S > 0 \; when \; T_f < T_i \; and \; \Delta S < 0 \; when \; T_f > T_i \, ,}$$

that is, the cooled body decreased its own enthalpy in an opposite direction to that of overheating (the meaning of indices is obvious).

This observation will soon be useful when talking about "Entropy and Life".

1.3   ANALOGY BETWEEN ENTROPY AND WEIGHT

The content of this paragraph is not essential for the purpose of this paper. However, we consider it useful to complete the understanding of entropy.

Amongst the physicists of the XIX century Zeuner (Germany 1828-1907) proposed an interesting analogy between the gravitational potential energy of a weight *P* and the entropy of a mass with a heat *Q* and a temperature *T*.

With reference to *Figure 1.4* we know that the potential energy (i.e. the mechanical work which can be performed) of the water mass of the reservoir is $L = P \cdot \Delta H$.

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[3] *It seems rational to accept the popular statement according to which the entropy of the astronomical universe is indefinitely increasing in spite of our lesser knowledge of the astronomical universe (see also the "Anthropic Principle"), in any case pay attention not to confuse that with testing a closed universe.*
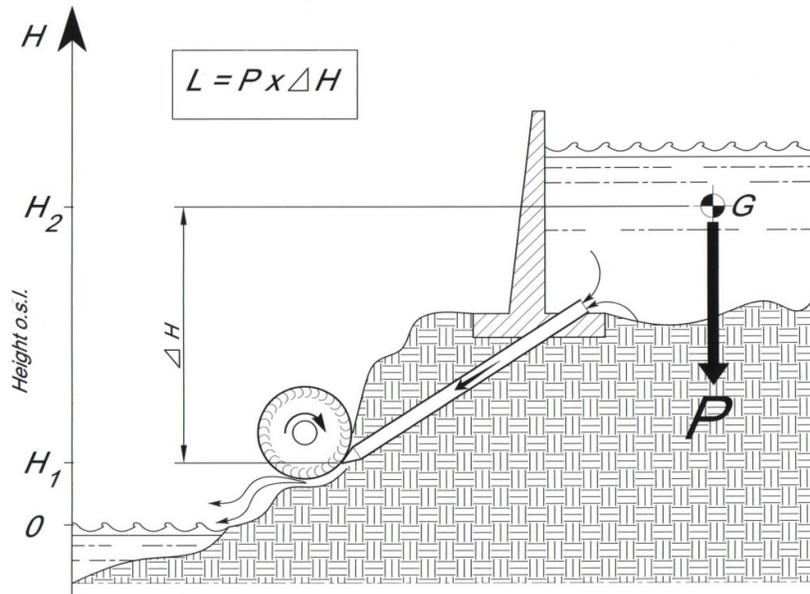
Figure 1.4 – System to transform gravitational potential energy into mechanical energy of a motor shaft.

Zeuner studied the work obtainable from a thermal motor capable of transforming heat into work with a Carnot Cycle[4], allowing the efficiency of the heat/work transformation to be expressed *exclusively in temperature terms* (as opposed to quantity of heat), which leads us to our goal.

In fact, as is widely known, the efficiency of the Carnot Cycle is

$$\eta = \frac{T - T_0}{T} = 1 - \frac{T_0}{T} \quad ,$$

where T-T_0 is the difference in temperature between *"source"* and *"coolant"* .

Consequently, introducing the quantity of heat Q into the motor, the mechanical work L obtainable will be:

$$L = \frac{\Delta Q}{T} \Delta T \qquad\qquad 2)$$

or rather, the expression that appears in *Figure 4*, where the **entropy $\Delta Q/T$ is a factor of proportionality analogous to the weight P,** where the change in height ΔH corresponds to the change in temperature ΔT which the motor is able to produce (from $\Delta"T < \Delta'T$ one has, in proportion, $L"<L'$, with the consequence that the residual internal energy, after being depleted and not able to be transformed into work, will be $U" > U'$).

We can observe that a functional tie exists between Q and T such that by increasing Q, T is increased in direct proportion (considering as constant the specific heat of the mass which runs the cycle, with no latent heat exchange) and therefore, given a particular initial entropy, the work obtainable depends exclusively on the ΔT achievable.

A motor which expels heat at a lower temperature produces more mechanical work at equal "consumption": this is the purpose of the comparison between the two thermal motors in *Figure 1.5* .

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[4] *A car run on petrol will produce an Otto Cycle, one on diesel a Diesel Cycle, an exothermic motor will produce a Rankin Cycle, etc.*