Concerning entropy

For those of you who require a fuller understanding of 'Entropy' then I offer the following extract from a thermodynamics paper written by L. J. Henderson (1917) Entitled '**The irreversible Universe'**

Thermodynamics and entropy

To begin with there was much dispute about the nature of heat. Many people thought of it as a sort of fluid, which could flow from one body to another. Eventually, it became clear that no such fluid exists and that **heat** is best defined as energy transferred because of a temperature difference. This scientific definition of the word 'heat' is slightly different from everyday usage, so it may help to consider a specific example. Think of a hot steak (veggie-burger, if you prefer) resting on a cold plate. The steak cools down and the plate warms up as energy flows from the steak to the plate. The energy transferred in this way is called heat. By contrast, **work** is energy transferred by non-thermal means. For example, if you rub the plate vigorously with a cloth, the energy of the plate will increase and it will get slightly warmer. But, this energy transfer is not *caused* by a temperature difference between the plate and the cloth, so energy transferred by rubbing is classified as work rather than heat.

In general, the total energy gained by a system (such as the plate) is the sum of the heat and the work transferred to it. It is worth emphasizing that heat and work are not themselves properties of a system. We cannot examine a plate and deduce that it has received so much energy from heat and so much energy from work. All that counts is that the plate has a total amount of energy, and that any increase in this energy is the sum of the heat and work transferred to the plate. This understanding of heat, work and energy is incorporated in the first law of thermodynamics.

First law of thermodynamics
When all types of energy transfer, including work and heat, are taken into account, the energy of an isolated system remains constant

From a modern perspective, we can see that this is just another way of stating the law of conservation of energy with the explicit recognition of heat as a quantity of energy to be included, alongside work, in any energy audit. Inventors should take note: an engine may convert energy from one form to another, but it cannot produce energy from nothing. The heat transferred to the steam, for instance, has paid for the kinetic energy of the piston of a steam engine, in advance.

Given this modern understanding of heat as energy transferred in a particular way, you might wonder why we bother to distinguish between heat and work at all. The reason is that heat can be used to define another important quantity: **entropy**.

We cannot define entropy properly in this introductory survey**. In very broad terms you can think of entropy as a measure of 'disorder' - the random motion of molecules in steam corresponds to more disorder, and hence**

more entropy, than the more orderly motion of molecules in ice. Interestingly enough, there is a connection between entropy and heat: whenever heat is transferred to a body, the entropy of that body increases. In the simplest case, if a small amount of heat $\boldsymbol{Q}$ is transferred gently to a body, whilst the temperature of the body is $\boldsymbol{T}$, the entropy of the body increases by $\boldsymbol{Q/T}$.

The term entropy was deliberately chosen to be reminiscent of energy, though the differences between the two quantities are just as important as their similarities. Entropy and energy are similar in that an isolated body may be said to have a certain 'entropy content' just as it may be said to have a certain 'energy content'. However, while the first law of thermodynamics ensures that the energy of an isolated system is always conserved, the second law of thermodynamics makes a slightly weaker assertion about entropy:

Second law of thermodynamics
The total entropy of an isolated system cannot decrease; it may (and generally does) increase

The requirement that the total entropy should not decrease has the effect of ruling out enormous numbers of processes that are perfectly consistent with energy conservation.

When heat flows between a steak and a plate there is no violation of energy conservation; the plate gains the energy lost by the steak. However, conservation of energy does not explain why the heat always flows *from* the hot steak *to* the cold plate; this is where the second law of thermodynamics comes in. Suppose the steak is at temperature $\boldsymbol{T}$, the plate is at a slightly lower temperature $0.95\boldsymbol{T}$, and that a small amount of heat $\boldsymbol{Q}$ is transferred from the steak to the plate.
Then the entropy of the steak decreases by $\boldsymbol{Q/T}$ while the entropy of the plate increases by $\boldsymbol{Q}/0.95\boldsymbol{T}$. It is easy to see that the entropy lost by the steak is smaller than the entropy gained by the plate, so the total entropy of the Universe has increased; this process is therefore consistent with the second law of thermodynamics. If, on the other hand, heat $\boldsymbol{Q}$ had flowed from the cold plate to the hot steak, the entropy lost by the plate ($\boldsymbol{Q}/0.95\boldsymbol{T}$) would have been greater than the entropy gained by the steak ($\boldsymbol{Q/T}$), and the total entropy of the Universe would have decreased. This violates the second law of thermodynamics, so we can be sure that the process is impossible. Heat flow is said to be an *irreversible* process - you will never see heat flowing spontaneously from a cold body to a hotter one.

You will never see heat flowing spontaneously from a cold body to a hotter one

Whenever energy is transferred or transformed, the final entropy of the Universe must be at least as high as the initial entropy. This usually means that heat flows are required to ensure that the total entropy does not decrease. Inventors should again take note. In most engines, heat is an unwanted by-product: the real aim is to transfer energy as work, perhaps to propel a vehicle or lift a weight. Since part of the energy initially stored in the fuel is inevitably wasted as heat, only a fraction is left to do useful work. Thus, thermodynamics imposes fundamental limits on the *efficiency* of engines. Fortunately, it also suggests ways of increasing efficiency, explaining for example, why a diesel engine is likely to be more efficient than a petrol engine, a topic we will return to in Classical physics of matter.

I hope that this helped in your understanding (or not, as the case may be) of the term. It certainly helped my understanding, many years ago. Haven't learned much since, but hey!!

This bit is 'Specially' for Sean: He He He….

I am sure Sean will appreciate this one (no chocolates for getting it correct though).. I know…Horrid person….He He. They make you fat anyway.

Entropy is generally defined not as an absolute value, but in terms of the change associated with the transfer of a small amount of heat:

$\delta S = \delta H/T$

Where δS is the small change in entropy associated with the transfer of the small amount of heat δH at 'Absolute temperature' T

NOTE: the requirement for 'Absolute Temperature'

This differential equation must be evaluated by the mathematical process of integration (or graphical/numerical equivalents of it) to find the change in entropy occurring over a large change in other properties.
Tables of values of entropy, as functions of temperature and pressure can then be calculated and charts plotted.

For water-steam, entropy is given the arbitrary value of zero at 0 ^oC (273 K).

What a load of *********

Have fun.

Sandy.