Thoughts on order, etc. occasioned by writings of J. P. Wesley.

Jeremy Dunning-Davies
Institute for Theoretical Physics and Advanced Mathematics (IFM) Einstein-Galilei,
Via Santa Gonda,
14 - 59100 Prato,
Italy
and
Institute for Basic Research,
Palm Harbor, Florida, U.S.A.
email: j.dunning-davies@hull.ac.uk

David Sands
Department of Physics, Hull University, Hull HU6 7RX, England
email: d.sands@hull.ac.uk

Abstract.

Although rarely, if ever, acknowledged, there is real confusion existing over several of the fundamental ideas of classical macroscopic thermodynamics. Many of these surround the concept of entropy and one of the big questions never publicly asked is whether or not the functions called entropy in various branches of mathematics and physics are all the same? Here some thoughts are presented which have been provoked by reading some of the writings of J. P. Wesley in the hope that they, in turn, will provoke further examination of these notions, many of which are so basic to so many areas of physics and are causing so much trouble for students at the present time.

Introduction.

In two papers published some years ago [1,2], Wesley, probably inadvertently, highlights some of the major concerns that should be being faced by all interested in the basis of classical macroscopic thermodynamics. Early on, Wesley introduces [1] a new 'law' which he labels a fundamental, or primary, law for processes in nature:

> "Natural statistical thermodynamic systems with temperatures greater
> than 2.7K open to deep space proceed toward states of lower entropy".

He claims that he is apparently introducing this law for the first time in this cited article but that it has been used implicitly for many years by cosmologists. He also goes to pains to stress that this new 'law' does not violate the Second Law of thermodynamics since the entropy decrease alluded to is much smaller than the increase in entropy of the Universe associated with the thermal energy of high entropy radiated off into space. Hence, it appears that all are satisfied. However, several points are raised in this paper and in the later article [2] which should be of concern. Already, in what has been written here, it might be noted that the new 'law' actually refers quite specifically to 'statistical thermodynamic' systems but the claimed decrease in entropy is then related to the usual Second Law of thermodynamics and is associated quite specifically with a heat change. Immediately, one is faced with the question of whether the two forms of entropy to which reference is made are, in fact, the same physical entity. Also, in both articles, the concepts of entropy and order are linked very closely and this raises further questions which, although rarely aired in the literature, really demand serious examination and answers.

Basic Thoughts on Classical Thermodynamics.

It should be noted from the outset that, almost by definition, there are possible implied differences between classical macroscopic thermodynamics and statistical thermodynamics. For example, consider the notion of entropy in each. In classical macroscopic thermodynamics only entropy changes are measured and, in effect, the zero of the entropy scale is simply undefined. However, that apart, the quantities measured are quite definite in nature and not subject to fluctuations. However, in statistical thermodynamics, the situation is somewhat different. As the name implies, a statistical approach is adopted in this field and that immediately introduces the idea of statistical fluctuations in the measurement of any quantity. These fluctuations, be they in the entropy or any other physical quantity, are introduced purely because of the statistical approach adopted; that is, it is the statistics which introduce the fluctuations into the values of quantities which really exhibit no actual fluctuation in nature. This thought must always provoke the question of whether or not particular fluctuations in the value of a physical quantity are real or merely a result of the approach adopted to examine a particular system.

Wesley also points out quite forcibly that he is concerned with open systems. He correctly draws attention to the fact that it is open systems which, in the main, exist in nature, not the closed systems often considered in classical thermodynamics. However, if one considers either of the original statements of the Second Law, one finds no mention of open or closed systems. Rather, in both these statements, there is emphasis on cycles and the absence of other effects. Note that the Kelvin statement is

> *It is impossible to transform an amount of heat completely into*
> *work in a cyclic process in the absence of other effects*,

while that due to Clausius is

> *It is impossible for heat to be transferred by a cyclic process from*
> *a body to one warmer than itself without producing other changes*
> *at the same time*.

The connection between these two forms is well-known [3] as is their connection with the more mathematical formulation due to Carathéodory [4]. It might also be noted at this juncture that the emphasis on cycles seen here is entirely understandable given the practical background to these forms of the law. Classical thermodynamics grew out of studies – both practical and theoretical - relating to heat engines since such engines were so vitally important for activities such as mining at the time. These engines effectively work in cycles and so emphasis on cycles is immediately understandable. However, as noted above, there is no mention in either statement of open or closed systems. In fact, the practical heat engine must be an open system as it operates in the local environment and some heat must, therefore, be lost to the surroundings; implying that the engine is not isolated from those surroundings and so cannot constitute a closed system.

Possibly the first important point to make is that, here, an author talks openly of systems undergoing decreases in entropy. This is something which is seemingly self-evident but is, on occasions, taken to imply, incorrectly, violation of the Second Law of thermodynamics. The form of the Second Law assumed at this juncture refers to the impossibility of entropy decreasing in certain carefully prescribed circumstances. However, it should be recognised immediately that that form is not a basic form of the Second Law of thermodynamics; it is merely a deduction from it – a deduction which may, or may not, be correct. It must also be remembered at all times that, as pointed out above, the basic Second Law refers quite specifically to cycles and a cursory examination of basic classical thermodynamics shows that processes in which entropy decreases are allowable. If not, how could a Carnot cycle be completed with no entropy change occurring at the end of the cycle? Hence, great care must be exercised when attempting to draw conclusions from apparent perceived entropy reductions. Of course, it could be that the only processes in which entropy does decrease are those which may be run forwards or backwards – referred to by some as reversible processes - since, by definition, if entropy increases during one of these processes, it must decrease during the other. This thought leaves it open for entropy to be allowed to increase during processes which may operate in one direction only but this restriction is never mentioned specifically when the so-called Principle of Increase on Entropy is discussed.

Entropy and Order.

As is highlighted by Denbigh [5], the linking of entropy and order is not always as straightforward as some would have us believe. Denbigh cites the well-known example of the expansion of a gas from one half of a container into the whole of the container. It is frequently claimed that such a process sees an increase in disorder since the individual molecules become more widely dispersed. However, as Denbigh points out, it could be argued equally well that the process sees an increase of order as the system becomes more uniform. He also discusses in some detail the spontaneous crystallisation of a super-cooled melt and points out that, if the process proceeds adiabatically, an entropy increase will occur. He then questions, though, how it can be reasonably claimed that the crystalline lattice is more disorderly than the super-cooled melt but this would be the case according to accepted interpretation of an entropy increase implying an increase in disorder. He comments that the explanation usually offered is a 'highly sophisticated way of looking at the matter and is theory dependent.' The conclusion is simply that entropy increase may not be interpreted in any reliable way as increase of disorder. In short, the whole link of the ideas of entropy and order/disorder is thrown into complete disarray.

In a note (17) on page 152, Denbigh points out that Hobson [6] 'has put forward a *definition* of disorder such that it becomes tautologically true, within the context of the information theory approach to statistical mechanics, that disorder very probably increases during an irreversible process.' He then proceeds to mention that Landsberg [7] suggests another definition. Landsberg discusses the point on pages 357 – 8 of the cited book and takes the presently accepted expression for the entropy gain of an open system in irreversible thermodynamics as his starting point. After a short discussion, he notes that the word 'order' has to be used with care but feels it can be given 'a quantitative definition which differs from that of entropy thus allowing *order and entropy* to increase together in special cases. These cases, which have not been discussed widely, can be considered to represent the emergence of *order from growth*.' He gives further details in his appendix I.5.

This short discussion on the part of Denbigh raises several interesting points but, possibly the most important in the present context, is the fact that, once again, the discussion centres on statistical thermodynamics, not classical thermodynamics. As usual, the principle of increase of entropy is assumed true and, although never mentioned, the concept of entropy itself is taken to be a single entity – that is, the notions of entropy in classical thermodynamics, statistical thermodynamics, statistical mechanics, statistics and information theory are all assumed equivalent.

This discussion by Denbigh raises huge questions about Wesley's discussions of both life and thermodynamic ordering of the Earth's surface and his subsequent analysis of order versus chaos in a steady-state cosmology, as well as questions on all other discussions of order/disorder, many of which occur in the biological literature when thermodynamic reasoning and ideas are applied to that discipline. As far as the Wesley work is concerned, however, another important point crops up also and that concerns how the entropy is evaluated in specific cases. Here Wesley is quite clear that he is utilising methods from statistical thermodynamics, not from basic classical thermodynamics. Indeed, as is often the case in actual practical examples, Wesley, like many other people, makes use of statistical techniques to evaluate the required entropies. This means, of course, that his entropy changes are not necessarily linked to heat flows into or out of the system in question and so, it may be asked if his entropies are actually thermodynamic entropies? It is always assumed, but rarely if ever admitted, that thermodynamic entropy as derived from the traditional statements of the Second Law is exactly the same as the entropy met in statistical thermodynamics and, indeed, in statistics and information theory. Evidence would suggest they often are the same but the question must exist as to whether they are *always* the same? Since true thermodynamic entropy is surely irrevocably linked with heat flow, it is difficult to accept this equivalence in situations where there is no heat flow but, if this is the case, what is this quantity which bears the same name as thermodynamic entropy?

Some Final Thoughts.

It has to be admitted that, when large collections of particles – as is the case in a gas for example – are under consideration, it is impossible to write down the exact equations of motion for all the individual particles, let alone solve such a vast set of simultaneous differential equations. Hence, the theoretician is forced to resort to statistical techniques. As is the case in so many fields, such techniques are extremely useful and lead to useful results and deep insight into many problems but no such investigation will be – in the true sense of the word – exact. As noted above, classical thermodynamics only measures changes in the quantity called entropy and so there is some uncertainty in that subject when it comes to setting a zero on the entropy measurement scale. Apart from that though, classical thermodynamics is a subject in which quantities may be measured exactly, or at least within the limits of experimental error. Once statistical techniques are introduced to derive formulae for such quantities as entropy in a particular case though, uncertainties are introduced but these are due to the mathematical methods used rather than to the situation existing in the basic problem. These thoughts reinforce the need to consider afresh the exact relationship between the quantities commonly referred to as entropy in the various branches of mathematics and physics in which they appear.

It might be noted that many of the ideas contained in the two papers by Wesley [1, 2] are covered also in his book *Selected Topics in Scientific Physics* [8] which is also a source of several other thought provoking ideas.

References.

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