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Introductory Remarks

W. H. McCrea

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Introductory remarks

By W. H. McCrea, F.R.S.
Astronomy Centre, University of Sussex, Brighton BN1 9QH, U.K.

What distinguishes modern physics from classical physics is the recognition of the role of fundamental (or universal) constants. Mathematical physics must be formulated so as to admit such constants; that is what distinguishes it from other applied mathematics. It is the particular values actually possessed by the constants that make our Universe what it is. Some analysis of this whole situation is the theme of this Discussion.

We contemplate essentially dimensionless constants, or, equivalently, constants expressed in natural units which exist because the constants exist. Naturally, however, values expressed in 'practical' units are an indispensable convenience.

The domain is one in which observation and theory are inseparable. For instance, had general relativity come without newtonian theory having been thought of, we should not have heard of the gravitational constant G. In this Discussion we learn about observations designed to test whether G varies with time. Now exactly the same observational procedures could be performed by astronomers who had never heard of G. They would express the purpose of the observations in other language. But this language would depend again on whether they had heard of cosmic time or not. Actually, however, in practice a different theoretical approach would probably have led to somewhat differently designed observations. Anyhow, the contemplation of such an example serves to illustrate how theory and observation interact.

At any point in our deliberation, it therefore seems inevitable that we should speak in terms of some definite *theoretical model* of the world of experience. There appears, however, to be no meaning in supposing there to exist a unique final model that we are trying to *discover*. We *construct* a model, we do not discover it.

Is it nevertheless true to say that models lead to the discovery of constants of physics? The answer seems to be yes, in the sense that a model may suggest a set of operations that is found to lead to the 'determination' of some constant. If so, then ever more refined repeatable observations are found to lead to a more and more 'accurate' value.

For, at any rate, most of our present purposes, I think it will be found that a constant of physics has this *operational* meaning. Any such constant is then entered in a table in decimal notation as a value with a standard error, and, of course, the specification of the physical units. Within our present understanding of physics, I would suggest that this is all that a 'constant' can ever mean. We cannot believe in the existence of a celestial 'Landolt–Börnstein' table in which every entry is a mathematically exactly defined number.

Having thus tried to say what is meant by the constants of physics, important general questions spring to mind that we wish to ask about them. Some of these prompted the proposal to hold the present meeting, and resulted in the sequence of topics on the programme. It may be useful briefly to indicate the pattern – a tolerably coherent pattern, as the organizers hope – as follows. The numbers are those of the contributions (here identified also by authors' names) as they were listed in the programme; I hope the contributors will regard my short descriptions as valid so far as they go.

Observation

Laboratory: values of the constants

1. Principles guiding experimental determination and accuracy sought therein. We learn about the nature of recent remarkable advances, although a systematic survey of the results is outside the scope of the discussion (Smith). Experimental data likely to be considered in next evaluation of the constants (Petley).

2. Constants concerned in rare phenomena that have acquired crucial special significance in recent times (Goldhaber).

Astronomy and geophysics: constancy of the constants

3. Results of precision observations in solar system astronomy (Reasenberg).

4. Exploitation of results of a naturally occurring geophysical experiment about 2×10^9 years ago (Irvine).

5. Exploitation of astronomical phenomena of some 2×10^{10} years ago (Pagel).

Theory

The constants in physics: field theories

The field theory aspect of physics is paramount in such studies at the present time.

6. Understanding the values. This survey makes precise, among other matters, some of those so briefly touched upon in this Introduction. Also it explores some possibilities for developments in the near future (Weinberg).

7. Possibility of a unified treatment of certain fields yielding relations between the constants: problems outstanding (Llewellyn Smith).

8. Field theories: their nature and genesis (Nielson).

9. Gravitation: a new view of its status as a field theory. A discussion like this is bound to give special attention to gravitation which is both the most familiar and the least understood field phenomenon in physics (Adler).

10. Unified theories: survey of the latest developments and their significance for determining and understanding the fundamental constants (Ellis).

The constants in cosmology

11. Early universe and its possible phase transitions. This is where certain of the concepts under consideration may find their most significant application (Kibble).

12. The problem of the cosmical constant – also mentioned in the preceding contribution – in relation to fundamental symmetries (Hawking).

13*. The origin and significance of certain 'cosmological numbers': possible relation to the constants of physics (Rees).

14*. The dependence upon the values of the constants of physics of macro-phenomena on the Earth and in the cosmos (Press and Lightman).

15. Dependence of physics upon the basic constant of dimensionality (Barrow).

16*. The anthropic principle and the significance for physical and biological theory of the values of the constants of physics (Carter).

Interest in the topics marked* in recent times originally instigated the proposal to hold this

Discussion. However, because of their speculative character and of their inability as yet to produce new predictions, it was considered that the main emphasis ought to be upon the study of the constants themselves rather than the role of the constants in these applications.

One hopes that this sketch shows there to be some logic in the general structure of the programme, even if not always in the precise sequence of the papers. However that may be, we may seem to be tackling almost everything in basic physics and in cosmology all at once. This is not the normally recommended way to achieve solid progress. But the ambition of physicists *is* to accomplish some grand unification; the following pages may serve to show what headway can now be claimed.

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