Sommerfeld

Difficulties arise also in relation to the units that have to be attributed to a concept. Do the dimensions of a concept have a reference in "reality"? Not only is it difficult to divide mathematical from physical quantities but it is also difficult to attribute to a physical quantity its dimensions; Planck and Sommerfeld in fact are in complete and explicit disagreement over this. As we will see below, Planck assumes as fundamental to his derivation of electromagnetic laws the Principle of Conservation of Energy and the Principle of Contiguous Action. This leads him to the following three expressions: for the density of electrical energy: (/8)E2; for the density of magnetic energy: (/8)H2; and for the flow of energy: S=(c/4) (E x H) where e is the dielectric constant and m the magnetic permeability.

Thus, of the five quantities involved (E, H, , , c), two have to be defined arbitrarily. Planck shows that the different possibilities are five. At the end of the discussion about which should be preferred and on what grounds, Planck expresses an extremely interesting point of view on the problem of what a ’physical’ quantity is:

"The fact that when a definite physical quantity is measured in two different systems of units it has not only different numerical values, but also different dimensions has often been interpreted as an inconsistency that demands explanation, and has given rise to the question of the ’real’ dimensions of a physical quantity. After the above discussion it is clear that this question has no more sense than inquiring into the ’real’ name of an object." (32)

Quite opposite to this is Sommerfeld’s approach in the preface to his Electrodynamics:

"The dimensional character of the field entities is taken seriously throughout. We do not accept Planck’s position, according to which the question of the real dimension of a physical entity is meaningless; Planck states in para. 7 of his Lectures on Electrodynamics that this question has no more meaning than that of the ’real’ name of an object. Instead, we derive from the basic Maxwell equations the fundamental distinction between entities of intensity and entities of quantity, which has heretofore been applied consistently in the excellent textbooks of G. Mie. The Faraday-Maxwell induction equation shows that the magnetic induction B is an entity of intensity along with the electric field strength E; B, rather than H, deserves the name magnetic field strength."

and:

"Energy quantities always take the form of products of an entity of quantity and an entity of intensity, e.g. ."

and:

"These questions of units, dimensions, and rationalisation, often discussed to excess in recent years, are disposed of as briefly as possible in the lectures; however the reader is repeatedly urged in them to convince himself of the dimensional logic of the formulas."

and:

"We may indicate finally a subdivision of physical entities into entities of intensity and entities of quantity. E and B belong to the first class, D and H, to the second. The entities of the first class are answers to the question ’how strong’, those of the second class, to the question ’how much’. In the theory of elasticity, for example, the stress is an entity of intensity, the corresponding strain, one of quantity, in the theory of gases pressure and volume form a corresponding pair of entities. In D the quantity character is clearly evident as the quantity of electricity that has passed through; in H the situation is slightly obscured by the fact that there are no isolated magnetic poles. We are in general inclined to regard the entities of intensity as cause, the corresponding entities of quantity as their effect." (33)