In contrast to QFD, where the gauge principle seems established and where we know how to calculate but the specific choice of model is open, there is only one plausible model in QCD, but too little is known yet about how to solve it to judge whether it is correct. Progress in this developing field is described in papers by Gross, Cornwall and 't Hooft. A paper by Politzer describes some work on the relatively well established applications of QCD to deep inelastic processes. There is also a useful review by Lipkin of the empirical status of the so-called Zweig rule, which is supposed to inhibit the decay of the J/ψ to hadrons so strongly. It is believed that QCD may explain this rule but in truth it is hardly understood at all. Similarly, it is hoped that QCD might account for the successes of hard scattering models of large P_T hadronic processes of the sort described in the paper by Feynman.

Many of the contributions to this volume are more or less directly based on, or form the basis for, papers which have now been published in regular journals. Despite this, most of the theoretical papers are worthwhile (I am not so sure about the experimental papers). The informal style of presentation makes them easy to assimilate and the reader can easily infer what the author really believes (unfortunately, the conventional style of journal writing often makes it hard to tell what parts of his work an author really takes seriously; perhaps we are too afraid that a frank style would give too many hostages to referees). This volume would therefore be a useful addition to libraries, although it is not the same essential work of reference as the proceedings of the one of the regular 'review conferences' (presumably it is beyond the reach of individuals at $71.40).

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Physics and technology of lightning

Lightning. Vol. 1: Physics of Lightning. Pp. 496. Vol. 2: Lightning Protection. Pp. 353. Edited by R. H. Golde. (Academic: London, 1977.) Vol. 1 £21; vol. 2 £17.

In spite of the volume of observational data which has been acquired in the laboratory and the field, the process by which clouds become electrified is still not understood; neither is there any agreement on a physical model for the initiation and propagation of the lightning discharge. Two groups of workers have been principally involved in this research. The atmospheric physicist interests himself in the electrical processes and their relationship to the cloud environment, whereas the power engineer concentrates on the more specific task of lightning protection. Dr Golde has reflected this division by separating this collection of reviews on all aspects of lightning into two volumes entitled *The Physics of Lightning* and *Lightning Protection*.

The power engineer faces the practical problem of the protection of buildings, and power and telecommunications systems from the damaging effects of lightning. Given a knowledge of the time variation of the lightning current at the point of strike, he has developed a series of devices to minimise any damage caused. On an empirical level he has been very successful. Electricity supplies are only infrequently interrupted due to lightning, and the deaths due to lightning strikes during underground blasting have been almost eliminated. Interference to telecommunications can be reduced to a tolerable level. Strikes to aircraft, and to microwave and television antennae will result in very little trouble being experienced if recommended practices are followed. The problem is mainly a matter of achieving maximum economic benefit. The chapters of the second volume comprise an impressive catalogue of the development and specifications of present techniques. Extensive reference to national and international recommendations should prove invaluable.

When we turn to the broader question of the physics of lightning itself, the situation is much less clear. Ideally for a complete description, we need to identify the microphysical and dynamical processes within clouds which lead to a separation of electric charge in agreement with the magnitude and position of the charges involved in cloud to ground and intra-cloud flashes. Next, we must explain the initiation and propagation of a conducting path within the cloud, leading finally to the observed current variation along the lightning channel and resultant electromagnetic radiation.

We are very far from such a comprehensive description. We have a vast array of observations from many parts of the world of parameters such as the time variation of lightning currents, leader velocities and the magnitude and heights of charges. It may well be that the lightning protection engineer with his demand for statistical information on frequency and intensity of discharges has resulted in many observers being pre-occupied by 'average' values of the above parameters which may vary over one or two orders of magnitude. Not surprisingly, it has proven impossible to fit the averages together into a coherent description of thet physical processes.

The editor has chosen acknowledged experts to deal with the different aspects, and each has produced an authoritative summary of the available information complete with exhaustive references. One omission is apparent. There is no chapter on the discharge process itself. Professor Allibone's chapter deals with the long spark between two electrodes, which is a practical problem in the insulation of electrical systems to withstand induced lightning transients. The lightning discharge is not initiated from a high capacity electrode but from within an initially insulating volume of cloud. In his 1969 book, Martin Uman described the physical models for leader and return stroke processes as being based on intuition rather than physics and being in a "lamentable" state. Should our lament continue? There is, for example, no discussion of the relative merits of the Schonland and Bruce models of the stepped leader in this book.

Controversy regarding the proposed charge separation mechanisms has been heated during recent years. It had for long been assumed that larger precipitation elements became negatively charged after interacting in some way with smaller cloud particles, and subsequent gravitational separation resulted in the observed high fields. This view has recently been challenged by the proposal that the convective motions within a cloud act like a giant Van der Graaf machine and that the precipitation development is incidental. It is refreshing to read the chapter by Professors Moore and Vonnegut carefully pointing out that the precipitation mechanism leads to contradictions and inconsistencies with observations, and suggesting that the convective mechanism could resolve some of these disagreements. There are few neutrals in this argument, so perhaps the best compromise would have been a second chapter giving the 'establishment' view of mechanisms, leaving the reader to judge.

During the past five years, we have seen the first steps towards a more ambitious form of lightning protection. Chaff has been dispensed within clouds in an effort to suppress lightning, and lightning has been triggered over land using rockets. It seems unlikely that there will be great progress in these endeavours until the basic problems of the physics of lightning are resolved. In their excellent chapter, Brook and Ogawa express the hope that a concerted effort using new techniques will lead to a far better understanding in a very few years. Meanwhile this first volume is a very useful summary of our present knowledge.

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