With a mass of the order of magnitude estimated here the temperature in question would be somewhere around 50° K, and practically all the thermal energy would then be in the form of electromagnetic radiation (the particles would contribute almost nothing, even if their temperature were many orders of magnitude higher). The average wavelength at that temperature (smaller than 1/10 mm) would be well within the region of validity of the Thomson formula and sufficiently small with respect to the average distance of the particles in the cloud (more than 100 mm).

Looking somewhat more closely at the possibility—suggested by the above estimates—of explaining the transition to the present state of the metagalaxy, it would seem that although the orders of magnitude are promising there is too little annihilation as well as opacity, if one makes the simplest assumptions : that the homogeneity of the cloud is conserved during the contraction and that the number of electrons is equal to that of the protons. There is no necessity, however, for the latter assumption—electrical neutrality being upheld by protons and anti-protons separately and positive and negative electrons separately—while a moderate increase of n_e (the number of electrons in each unit volume) would give sufficient opacity. The limit would probably be given by the highest permissible value of n_e in the present state of the system, taking into consideration the decrease of this quantity resulting from expansion and annihilation. Verification of the approximate temperature equilibrium as well as of the explanation of the expansion by means of radiation pressure can perhaps be seen in the observed low-temperature radiation mentioned at the beginning of the article. Thus, if the radiation expands in doing work on the electrons, the opacity being sufficient, its temperature would decrease approximately in the same proportion as the linear dimensions increase, that is, by about a factor of ten according to the estimates of a and a_0. Within the uncertainties this would agree well with the temperature (about 3° K) of the present radiation.

As to the other difficulty, it would be removed if a sufficient number of inner condensations appear inside the cloud during its contraction, their time scale being shorter than that of the general contraction, as a result of their higher density. Such an occurrence produced by inner instabilities seems highly probable. Assuming a mass of such a condensation of the order of magnitude of a galaxy, considerable annihilation would occur quite long before its opacity is sufficiently great to stop the contraction and very long before the Schwarzschild limit is reached.

Here also another point should be mentioned, namely the transfer of the momentum given to the electrons from the radiation to the protons of the cloud. According to Alfvén this would be brought about by the magnetic fields necessarily present in a thin plasma of electric particles.

Thus, as already mentioned, a considerably smaller mass would develop in a manner differing widely from that of a metagalaxy, the lack of sufficient opacity impeding largely the braking of the contraction by means of radiation pressure. Here one would expect that the magnetic fields—implying the Alfvén separation—would become important and lead to the development of a galaxy or a galaxy cluster but not to a metagalaxy. A much larger mass, on the other hand, would scarcely suffer any significant annihilation before inner condensations had appeared because the Schwarzschild limit density is inversely proportional to the square of the mass.

Further reading:

For orientation in cosmology:

North, J. D., *The Measure of the Universe. A History of Modern Cosmology* (Oxford University Press, 1965).

For the alternative:

Alfvén, H., and Klein, O., *Arkiv för Fysik*, **23**, 187 (1962)—where earlier work is quoted.

Klein, O., *Astrophys. Norveg.*, **9**, 161 (1964).

Klein, O., *Boundary Conditions and General Relativity, Preludes in Theoretical Physics*, 23 (North-Holland Publishing Company, Amsterdam, 1966).

Alfvén, H., *Rev. of Mod. Phys.*, **17**, 652 (1965).

BOOK REVIEWS

ORIGINS OF INVENTIONS

A Social History of Engineering

By W. H. B. Armytage. Second edition. Pp. 378+36 photographs. (London: Faber and Faber, Ltd., 1966.) 50s. net.

THE aim of this book is "to chart technological developments with special reference to Britain, to indicate how they have affected and been affected by social life at certain stages and to offer some clues as to the origins of innovations and motivations". This is a far from modest aim for a book of less than 400 pages which starts its story in 3000 B.C. and ends with the problems posed by space, high energy physics and the power revolution.

The book is one of a series designed for the student and professional scientist and technologist, and for such a public the treatment of technological developments and of the relevant scientific discoveries is sketched in with a fine sense of perspective and economy. It is not a book for the general reader, for whom inevitably, in a book of the size, there is not enough description of the inventions listed.

The treatment of how technological developments affected and were affected by social life is less satisfactory. The analysis of the interaction between technology and education, and also of the ways in which, from time to time, necessity has mothered inventions is well done. But in dealing with the effects of technological developments on social life Professor Armytage has been much less successful. If a third edition of this book is published it is to be hoped that Armytage will have more to say about the social impact of changing war technology, about the effects of changing technology on family life, social mobility, the location of industry, the distribution of income, the forms and concentration of economic and political power, and so on. Attention to such analysis, deriving from Marx, Weber, Sombart and Durkheim, should help to add to the engineer's understanding of the "social, political and philosophical implications and consequences of his work and influence in society at large".

The final aim of the book—to offer some clues as to the origins of innovations and institutions—is fairly well accomplished. In a book on the social history of engineering, however, it is a little disappointing not to find rather more discussion of the relations between science and engineering and, in terms of economic development, possible conflicts between them. How many countries have been successful in both together ? Armytage touches on this problem in his treatment of Greece and Rome but does not take it much further. In contemporary Britain he simply treats research as the key to innovation, without much attempt to examine the problem of the best allocation of scarce scientific and engineering manpower between alternative uses. Here too I hope that the third edition of this book will include a discussion of the complex economics of research, development and innovation.

BRUCE WILLIAMS

ARCHAEOLOGICAL FINDINGS

The Annual of the British School at Athens

No. 60. Pp. 345+86 plates. (London: The British School at Athens, 1965.) 105s. net.

THE British School of Archaeology at Athens enjoys a high reputation in archaeological circles, not only for the general competence of its research and excavation organization but also for providing a wide range of papers