Certainly even the eighteen poisons used by the Germans and the counter-efforts actually brought into operation by the Allies were the fumbling of experimental amateurs compared with what might follow a new outbreak of hostilities between great manufacturing and scientific nations. Poison could suddenly extinguish all life over so many square miles of territory, over a walled city, or a navy in its harbor. Science could provide the formula, industrial chemistry the substance, and aeroplanes the means of distribution. Were poison gas a specialized and secluded branch of chemistry there might be some hope that science might refuse to pervert its high mission from the service to the destruction of mankind. But such a possibility does not arise, because the discovery of noxious substances is an inevitable side issue of the pursuit of chemical knowledge. The world must either face and prepare for the future, or it must prohibit chemical warfare by an international agreement supported by effective international sanctions.—The London *Times*.

SCIENTIFIC BOOKS

BIBLIOGRAPHY OF RELATIVITY

THE great interest in any scientific or philosophic discovery generally calls forth semi-scientific and learned discussion, followed by a demand for literature, historical and recent, upon this particular subject.

The literature of the theory of relativity is recent and more or less familiar to the scientist. Before 1905, the year in which Dr. Albert Einstein brought forward his fundamental and special theory, the literature was scattered and bore indirectly upon the theory of relativity as we know it to-day. The literature is quite extensive, however, from 1905 to the time of the British solar eclipse expedition in May, 1919, the results of which placed the theory of relativity in a more or less acceptable light, that is, the mathematical and physical aspects found verification in the astronomical interpretations.

In view of the fact that the subject of relativity will probably have great influence upon future problems in physics and astronomy, due to its mathematical character, and that the history of this development can best be served when the literature is known and organized, a bibliography should prove of great value.

The present note is to call attention to the fact that an extensive and as complete a bibliography as is possible, is in process of being compiled. And thus far the writer has collected approximately one thousand titles of books, pamphlets, articles and notes published in all languages to which it is possible to obtain access. The John Crerar Library seems the most logical place to form this bibliography due to its great collection of scientific literature. The philosophical literature bearing upon this question (relativity) fortunately falls within the scope of the library's collection.

It is hoped that each entry upon the typewritten card will contain, besides the author, title, source, date, also a short abstract, note or review indicating just what the principal idea is that the author has conveyed. A mere author-title list is for current use and answers only half of what a true bibliography ought to be, and therefore is quite unsatisfactory. Over 90 per cent. of the titles represent material in The John Crerar Library, and it is planned to make the collection in the library as complete as possible, bearing upon relativity.

The question of publishing this bibliography is a difficult one, and at present no provision has been made for it.

What form of bibliography will be most valuable for scientific purposes is an open question. There are as many types as there are demands for certain use. An alphabetical author-title list serves one certain demand, and a chronological author-title list serves another. One might be analytical and another synthetical in its aspect. A synthetical bibliography must be selective, critical and constructive[1]; add to this abstract, notes and reviews, and it would be a bibliography worthy of its name.

[1] Dr. George Sarton, *Isis*, III., 159–170, No. 8, Autumn, 1920.

From the point of view of the future historian this would serve as a large labor-saving device, especially in view of the fact that human knowledge is ever becoming more specialized.

It might be well to call attention to the fact that a bibliography of relativity has also been in progress in England,[2] namely, the International Catalogue of Scientific Literature, under the direction of Dr. H. Forster Morley. Dr. Morley has made a selected chronological bibliography of relativity and related problems from 1886 to the end of 1920.

The recent visit of Dr. Albert Einstein has not alone stimulated interest among scientific men, but he has strengthened his theory by his own clear presentation of relativity.

Of course the theory has yet to receive its final verification, before the whole can be accepted, and Dr. Einstein has expressed confidence in the final answer.

Not since the doctrine of evolution was promulgated, has any advance of intellectual progress, either of philosophic or scientific importance, caused such profound interest, popular or scientific, as the theory of relativity. And like all epoch-making ideas, the synthetical character of the theory of relativity will mark off a period of great importance in the history of science. Hence the value of a bibliography of a subject in relation to the history of science is in direct proportion to the importance of the subject itself.

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[2] Dr. H. Forster Morley, *Nature*, 106, 811–13, Feb. 17, 1921.

SPECIAL ARTICLES

EINSTEIN'S COSMOLOGICAL EQUATIONS

IN two earlier notes published in SCIENCE (Vol. 52, p. 413, Vol. 53, p. 238) I gave certain geometrical theorems connected with Einstein's original (1914) equations of gravitation, $G_{ik}=0$ (in space free from matter). I shall now extend some of the results so as to apply to the modified equations employed in Einstein's cosmological speculations. These he first wrote (1917) in the form, $G_{ik}-\lambda g_{ik}=0$; but more recently (1919) he has employed the form $G_{ik}-\frac{1}{4}g_{ik}G=0$, which includes the previous form and which, when the energy impulse tensor T_{ik} is introduced in the right hand member, has the advantage of being possibly applicable to the microcosm (atoms and electrons) as well as to the macrocosm (the stellar universe). Here G_{ik} is the contracted curvature tensor and G is the scalar curvature.

For brevity we shall term any four dimensional manifold which obeys the last equations, a cosmological solution.

I. The only cosmological solutions which have the same light rays as the euclidean or Minkowski world are those which have constant curvature in the sense of Riemann. In other words, if a cosmological world is to admit conformal representation on a euclidean world, it must be of spherical (or pseudospherical) character. This result is analogous to the earlier result for $G_{ik}=0$, that the only manifolds having the Minkowski light equation are flat (zero curvature). Both results are obviously valid also for geodesic representation (same equation of orbits).

II. Here we discuss four-dimensional curved manifolds which can be regarded as imbedded in a flat space of five dimensions. Our result is that for the cosmological equations, there are two distinct possibilities.

(*a*) In the first case at every point of the manifold the four principal curvatures are equal, that is $K_1=K_2=K_3=K_4$, so that every point is umbilical. The manifold is then simply a hypersphere.

(*b*) In the second case $K_1=K_2=-K_3=-K_4$, that is, the four principal curvatures are numerically equal, but two are positive and two are negative. Such manifolds may be regarded as a generalization of ordinary minimal surfaces (where $K_1=-K_2$), and may be described as hyperminimal spreads. (It would be interesting to find an actual example in finite form of such a spread.)

It will be recalled that for our previous discussion of $G_{ik}=0$, no solution in five dimen-