method, have been obtained by Harkins and his co-laborers in Chicago. According to Aston, the mass spectrum of mercury shows two lines at 202 and 204, with four others of uncertain significance between 197 and 200. These figures, it seems to me, are questionable, for 197 is the atomic weight of gold, and 204 that of thallium. Did the mercury studied by Aston contain as impurities minute traces of gold and thallium?

By prolonged fractionation Harkins has divided hydrochloric acid into two portions which differ in atomic weight and density, thus showing that chlorine, like mercury, is composite. But for neither element has the separation of its components been complete. That one component is more massive than the other is clear, but the definite atomic weights of the two elements show a constancy of composition which calls for explanation. We are not dealing with indefinite variable mixtures.

I now venture to offer a hypothesis which is at least fairly plausible. In the evolution of the elements some of them were generated as doublets in which the components are loosely held together, but which in their chemical relation act as units. We can conceive of such doublets as analogous to double stars, those pairs of suns which move and act together, notwithstanding their differences in mass. Whether this analogy can be extended to the elements that give multiple mass-spectra remains to be seen. About half of the known elements are yet to be studied by Aston's methods, and the work is being carried forward energetically. When it is finished we may hope to know much more as to the relative significance of atomic weights and atomic numbers, and as to the real nature of the chemical elements.

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MATHEMATICS AND GEOPHYSICS[1]

Geophysics is physics applied to the study of terrestrial phenomena. To make the statement more definite it may be of interest to enumerate the subdivisions of this science as formulated by the National Research Council in organizing the American Geophysical Union. That union includes sections of: (1) Geodesy, (2) oceanography, (3) meteorology, (4) seismology, (5) terrestrial magnetism, (6) volcanology and (7) geophysical chemistry.

To the student of geophysics, as to the student of physics in the narrower sense, there are open three ways for discovering truth: (1) Observation of phenomena under controlled conditions, in short, laboratory experiments; (2) observation of phenomena as they are presented to us by nature; and finally (3) logical deduction from assumptions suggested by observation and experiment and comparison of the conclusions reached with the observed facts. The most satisfactory method of deriving our conclusions is by mathematical reasoning, since this method alone gives quantitative results.

From the nature of the case the methods of laboratory experiment have been of less use in geophysics than in physics in the narrower sense. The experimenter can reach only a few miles into the upper air with his pipes and balloons carrying their recording apparatus and must himself remain on a still lower level. Our deepest borings penetrate but a few thousand feet into the outer skin of the earth[2] and the interior of the earth still remains, as has been well said, the playground of the imagination, almost as much so as when Dante peopled it with the spirits of the departed.

It would, however, be unfair to insist on this thesis of the comparative inapplicability of laboratory methods to geophysical problems without mentioning the work of the Geophysical Laboratory, a department of the Carnegie Institution, which is in fact applying laboratory methods to these problems and applying them with marked success. Still, with every allowance of this sort made, in geophysics the methods of the physical laboratory can do little for us in comparison with what is possible in other sciences.

Therefore, in geophysics we must depend all the more on the observation of those phenomena directly presented to us by nature and on mathematical reasoning. A striking example of this method or combination of methods is found in recent progress in our knowledge of that still mysterious region just referred to, the interior of the earth. Important advances have been made which I shall not attempt to set forth by combining the observations at earthquake stations all over the globe and applying to these observations mathematical methods of rather recent development, the theory of integral equations.

Now it would be impossible for any one person to discuss satisfactorily all the problems in geodesy, seismology, oceanography, etc., in which mathematics has given aid, or which still await the hand of him who shall apply existing mathematical methods to them, or who, if need be, shall devise new methods.

[1] Read at the summer meeting of the Mathematical Association of America at Poughkeepsie, N. Y., September 5, 1923.

[2] The greatest authenticated height reached by a sounding balloon bearing instruments is 35 kilometers. A pilot balloon without instruments is reported to have reached the height of 39 kilometers, but this record is open to doubt (information supplied by U. S. Weather Bureau). The deepest boring in the world is at Fairmont, West Virginia. The depth is 2310 meters (7579 feet) (information supplied by U. S. Geological Survey).

And even if the whole corps of specialists necessary for such an exposition were present here, the entire time allotted to this meeting would be far too little even for the baldest of treatments, so I shall confine myself to a few statements chiefly about two general subjects which may perhaps be of interest to teachers: (1) The use that may be made of comparatively elementary methods and (2) numerical calculation.

Before entering on these two matters it may be pertinent to make the obvious remark that the mathematical treatment of geophysical problems is included in the treatment of the problems of general mathematical physics. It may also be pertinent to ask why mathematical physics has been so little studied and developed in this country, so little, that is, whether we base our comparison on the attention given to the allied subjects of pure mathematics and experimental physics, or whether we base it on the attention given to mathematical physics in the countries of Western Europe. I ask the question, but do not attempt to answer it, for one reason because I can not do so satisfactorily, and must, therefore, leave the answering to you.

The use of elementary mathematics is rather in clearing the ground of unprofitable speculations that hinder the advance than in making the advance itself. Speculation has been uncommonly rife in geophysical fields, and those who have put forward suggested hypotheses have not always deigned to test them even by rough and easy calculations which might have shown their untenability and thus saved the time of hearers, editors, typesetters and readers. It is frequently as easy to set rough numerical limits which will show whether or not an idea is worth pursuing further, as it is difficult to work out an accurate theory. It is evident that according to the law of gravitation it will make a difference in what happens on our earth according as some hypothetical inhabitants of the planet Saturn do or do not build a subway there, but it will be granted without much calculation that we do not need to care, as far as any effects that we can now detect may go, whether or not they build a whole system of subways. Now in geophysical speculation some of the causes suggested have been about as inadequate to the effects as the Saturnian subways would be to explain variations in our terrestrial climate.

As a recent example, take the Wegener hypothesis of the migration of continents or rather one explanation of this migration. According to the Wegener theory a continent is not securely fastened to its foundations, but is capable of moving as a whole, much as an iceberg moves through the surrounding water. The motion is in general westward. Now there is a very minute force which might—I doubt whether in fact it does—displace such a continental mass, not westward but towards the equator. The rate of motion would be at most a few inches or a few feet a year. Now Wegener suggested that such an equatorward force together with the deflecting force of the earth's rotation might produce the postulated westward motion of the continents, just as the equatorward currents of air are deflected by the rotating earth and give rise to the westerly component of the trade winds.

The importance of a rather high equatorward velocity such as the air currents have and the continents have not, even on the most favorable supposition, seems to have escaped Wegener. It is only fair to add that this absurdity was removed in a later edition of Wegener's book, but not before it had inspired a very similar absurdity. A reader of Wegener reasons thus: A falling body is deflected towards the east and if it fell down a narrow vertical tube, it would press against the eastern wall of the tube. By analogy, therefore, a mass of rock slowly sinking would press against the eastern side of the rocks surrounding it or a slowly rising mass of rock press towards the west. True enough qualitatively, but if we consider the rate at which rocks rise or sink, the utter unimportance of the effect is easily proved. Yet this suggestion was put forth in good faith and reproduced in good faith in the pages of scientific journals of standing.

A consideration of the dimensions of the quantity aimed at is a useful check on algebraic work and the application of it may save one from humiliating blunders. One author, discussing the póssible effect of variations of latitude in producing earthquakes, makes a "howler" in the fundamentals of his calculus for which a sophomore would deserve to be called down sharply. Yet even so, he might have sensed that something had gone wrong and so saved himself if he had only examined the dimensions of his result and noticed that his expression for the intensity of stress was of the wrong physical dimensions.

These remarks apply equally well to many subjects other than geophysics. It is a question quite as much of mental attitude as of any mathematical rule or theory. What I shall now say about numerical computation is of almost equally general application.

It has long seemed to me desirable that more attention should be paid in our mathematical courses to numerical computation. In geophysical work, dealing as it does with vast masses of data, this is especially desirable. Yet our mathematical curricula are already overcrowded and it is not easy to see where a place could be found. Furthermore, text-books in English are almost totally lacking. Perhaps a well-written book on the subject might draw enough attention to the importance of the subject so that it would be more generally taught.

I should like to see such a book that would set forth on the elementary side the best arrangement of work, the accuracy desirable and attainable in any given process, short cuts, rough approximations and rough checks and on the more advanced side, in the use of differences, interpolation, mechanical quadrature, numerical solution of equations, calculations with infinite series.

Even more advanced topics might be introduced, but that question involves another aspect of numerical calculation about which I wish to say a few words in closing. The solution of problems for mathematical physics in general, and of many problems in geophysics in particular, are often satisfactory enough from the purely analytical point of view, but rather unsatisfactory from the point of view of numerical calculation. It would be desirable if mathematicians would think more of this aspect of the question, for, after all, the final test of a theory is numerical comparison with the results of observation. The book on numerical computation of which I have spoken might contain as a second part a discussion of the numerical solution of differential equations, of integral equations, of the treatment of series that converge for the pure mathematician, but not for the practical computer, in short, a number of topics continually increasing as our mathematical theories develop. The easiest way to have such a book kept up to date would be for each mathematician who develops a theory that leans in any way towards practical application not to leave the analysis until he has considered the question of putting his formulas into numbers by the easiest and safest way.

These remarks can be summarized very briefly: Geophysics involves mathematics to a greater extent than do most physical sciences. Elementary mathematics is involved because of the extensive tabulations and numerical computations that are required. Even elementary mathematics, judiciously used, may serve to check the vagaries of an over-active imagination and to warn the inquirer off paths that lead nowhere, except perhaps to confusion. Advanced mathematics is needed, not merely because geophysics is a part of mathematical physics in general and has given rise to many interesting mathematical problems, but chiefly because geophysics is peculiarly dependent on mathematical methods.

W. D. LAMBERT

U. S. COAST AND GEODETIC SURVEY

SCIENTIFIC EVENTS

THE LONDON MUSEUM OF SCIENCE AND TECHNOLOGY

THE resolution given below in regard to the London Museum of Science and Technology has been adopted by the Royal Society, the British Association for the Advancement of Science, the British Science Guild and about thirty other scientific societies of Great Britain, and has been submitted to the Board of Education:

We the undersigned, being deeply interested in the progress of science and in its application to industry, desire to bring to the notice of H.M. Government the inadequacy of the accommodation provided for the collections at the Science Museum, and the disadvantages resulting to science and technology therefrom. Several committees have reported on the Science Museum, notably in 1874, 1884, 1889 and 1912, and all of them have emphasized the importance of the collections and the value of the assistance which they can give to science and industry; they have also commented on the unsatisfactory character of their accommodation; to-day the Science Museum is still the only national museum housed in buildings most of which were neither designed nor constructed for museum purposes.

The collections which illustrate the development of science and of large and important branches of technology are in some respects unique. They include many selected examples of modern practice and are of the greatest value to students as well as to investigators and all who are concerned with these departments of knowledge, but they can not be fully utilized for consultation and study in the crowded and insufficiently lighted galleries where they are now displayed, while the risk from fire is very great.

The Departmental Committee which reported in 1912 considered that a total of 265,000 square feet of exhibition space was immediately necessary, which should be increased subsequently by an additional area of 287,000 square feet. They sketched out a plan for a building in three blocks, and recommended that the immediate need should be met by the erection of the Eastern and Central Blocks. We understand that the work at present authorized will bring the exhibition area up to a total of 120,000 square feet only, or less than one half of what the Committee recommended, and only about 30,000 square feet in excess of that now available.

We venture, therefore, to urge upon H.M. Government the importance of completing the whole of the Eastern Block of the new Science Museum building forthwith, thus raising the space available for exhibition to 180,000 square feet, and since this will not provide all the space which was considered immediately necessary in 1912, of preparing plans for a central block as soon as possible.

STANDARDIZATION IN GERMANY

STANDARDIZATION of industrial production has been one of the important factors in enabling Germany to maintain its industrial machine intact, in the face of the obstacles now confronting that country, according to a bulletin by Dr. P. G. Agnew, secretary of the American Engineering Standards Committee, recently issued by the American Engineering Standards Committee. Dr. Agnew recently returned from Europe,