stituted a so-called fluid-friction theory—imperfectly defined, little understood and based on fallacious reasoning.

To compare for a moment the two theories: our fluid-friction theory lays it down fundamentally that a fluid devoid of viscosity offers no resistance to uniform motion through it. This theory has now enjoyed a long scientific inning, but it has not yet enabled any one (to my knowledge) to calculate the resistances of bodies of the simplest form.

Newton, in his theory, lays it down fundamentally that a fluid devoid of viscosity *does* offer resistance, and that such resistance varies as the density of the fluid and as the square of the velocity of the body moving uniformly through it.

In the "Opticks" (Query 28)—in 1718 and therefore his matured view—he is more precise, and says the resistance of a sphere "which arises from the attrition of the parts of the medium is very nearly as the diameter, or at most, as the *factum* of the diameter and velocity of the spherical body together. (Thus anticipating what we call "Stokes Law.") And that part of the resistance which arises from the *vis inertiae* of the matter is as the square of that *factum.* And by this difference the two sorts of resistance may be distinguished from one another in any medium; and these being distinguished it will be found that almost all the resistance of bodies of a competent magnitude moving in air, water, quicksilver, and such like fluids with a competent velocity, arises from the *vis inertiae* of the "parts of the fluid." And a little later he again says:—"The resistance of water arises principally and almost entirely from the *vis inertiae* of its matter."

The calculation of any resistances by our fluid-friction theory being admittedly impossible, would it not be an appropriate tribute to Newton's memory to give his own *peregregia theoria* a place in his bicentenary year? Resistances *can* be calculated by Newton's theory to a high degree of accuracy, as was shown by Colonel Duchemin more than eighty years ago.

For another comparison, take the case of water flowing out through a one-inch circular thin-walled orifice. Calculating in the ordinary manner we obtain a figure which we may call 100, while we know that by experiment we shall get a figure about 62.5. We have accordingly to employ a coefficient of 0.625 before our result is of any value at all. Such a method scarcely deserves to be called scientific. The condition is really worse than this, for our coefficient is not even constant but must be varied as the diameter varies.

On the other hand, by Newton's theory the discharge for a one-inch orifice can be calculated directly to within the second place of decimals of the experimental amount. Surely we should be consulting our own practical advantage, as well as honoring Newton's memory, by at least finding a place for his theory—a theory which leads at once to a correct result—alongside one which is useless without what may be called a "judging" coefficient.

If it be asked why it is assumed that a fluid devoid of viscosity offers no resistance to uniform motion, the answer may be found in the first three lines of Lamb's "Hydrodynamics."

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SCIENTIFIC BOOKS

American Silurian Crinoids. By FRANK SPRINGER. Publication No. 2871, Smithsonian Institution, 236 pages, 32 plates, 1926.

MANY-SIDED Frank Springer, born in 1848 in Iowa, educated there and admitted to the bar in 1869, has long been America's foremost authority and the world's most prolific worker in the field of fossil crinoids. Beginning his scientific career in 1877 with an adopted son of Iowa, Charles Wachsmuth, their joint publications continued until 1897 (sixteen titles). Since then, Springer has carried on his studies of crinoids alone, and has added to his bibliography fifty-seven scientific titles, besides forty-six other miscellaneous papers having to do with law and public affairs. His results are fundamental in crinoid morphology and taxonomy. Since 1873 he has been a citizen of New Mexico, where he became one of the state's leading men and also amassed a fortune. A good part of the latter was used in getting together the largest collection of crinoids, blastoids and cystids anywhere, and after describing and illustrating these rarities as no other worker has, he gave them unencumbered to the nation through the Smithsonian Institution. Crinoids, and especially whole ones, are usually very rare fossils, but when good leads are gone after with pick, shovel and powder, as many have been under Springer's direction, the results are astonishing, as is again attested in the beautiful and monumental work under review. The drawings, by Kenneth M. Chapman, are very fine, and the half-tone reproductions are the best we have ever seen.

In "American Silurian Crinoids," 198 forms (seventy-four new) in sixty-three genera (seven Camerata are new) are discussed and illustrated, but not all these are of Silurian time, nor are all the American forms included. Rather is it the species found in Tennessee, Indiana and Kentucky that are dealt with, so that the total number of forms of this period in our country must now exceed three hundred. A number of species "are scarcely distinguishable from English and Swedish forms," and this is all the more remarkable in these very intricately plated animals. Out of the sixty-three genera, thirty-three are common to Europe and America. The reviewer is further surprised to see no fewer than nine species (seven are of *Pisocrinus*) common to the southern and northern Silurian seas of the United States, showing that these waterways must have been in open connection.

The monograph also describes those most anomalous of all crinoids, the Calceocrinidæ, some of which have been called "dead men's fingers." Here the crown, starting with the normal number of radii (five), gradually eliminates two of them, and the head is reversed or recumbent upon the stem, a peculiar evolution which the author thinks was due to the stalk or stem being prostrate on the ground, with the crown in the horizontal attitude when feeding. Springer brings together all that is known of these highly specialized American and European crinoids (four genera and twenty-eight species), ranging from the middle Ordovician to the Mississippian (Keokuk), and successfully traces and illustrates their trends of evolution. The Calceocrinidæ are, he says, "an example of evolutionary modification with the process clearly visible, that is without precedent among the crinoids" (p. 71). Their singular modification out of normally developed Heterocrinidæ is due to the fact that "the base is united to the radials by a hinged muscular articulation, allowing motion of the crown above the base up and down in the plane of its bilateral symmetry" (p. 88).

Would that the human world had more men like Frank Springer!

CHARLES SCHUCHERT

SPECIAL ARTICLES

PROPERTIES OF SUBSTANCES IN THE CONDENSED STATE AT THE ABSOLUTE ZERO OF TEMPERATURE

IN a paper read at the Philadelphia meeting of the American Association for the Advancement of Science the writer deduced from results of an axiomatic character a result which may be stated in the form that the controllable internal energy and entropy of a substance or mixture in the condensed state at the absolute zero of temperature are zero, and that this zero corresponds to the mathematical definition of a minimum in the Calculus.[1] The result includes the third law of thermodynamics and Nernst's heat theorems. A number of deductions may be made from it which are of considerable interest and importance. These can not be deduced, it may be mentioned, from the third law of thermodynamics or from Nernst's heat theorems. The deductions of some of these results are given in a paper read at the February meeting of the Physical Society held in New York City, of which a few will be given here because they open up a new field of experimental research.

It is shown that besides

$$C_v = 0 \tag{1}$$

for any substance or mixture in the condensed state at the absolute zero of temperature, we also have

$$\left(\frac{\partial' C_v}{\partial' T}\right)\frac{1}{v} = 0 \tag{2}$$

where C_v denotes the specific heat at the constant volume v, and T the absolute temperature. Experimental evidence of the truth of these two equations already exists. According to Debye's formula for the specific heat of a monatomic solid, which is found to agree well with the facts, the specific heat near the absolute zero of temperature is given by

$$C_v = a_1 T^3 \tag{3}$$

where a_1 is a constant. This equation has been specially investigated by Kammerlingh Onnes and found to agree well with the facts.[2] Equations (1) and (2) evidently agree with it. Experiments on the specific heat of mixtures near the absolute zero of temperature besides on monatomic solids would be very desirable.

If U denotes the internal energy of the substance or mixture, and it may be expressed as a series of integral powers of T by Taylor's theorem,

$$U = a_2 T^3 \tag{4}$$

near the absolute zero of temperature, according to equations (1) and (2), where a_2 is a constant.

It is also shown that besides

$$p = 0 \tag{5}$$

we have

$$\frac{dp}{dT} = 0 \tag{6}$$

and

$$\frac{d^2p}{dT^2} = 0 \tag{7}$$

where p denotes the vapor pressure of the substance or mixture. Therefore, if p may be expressed in integral powers of T by Taylor's theorem

$$p = a_3 T^3 \tag{8}$$

near the absolute zero of temperature, where a_3 is a

[1] See SCIENCE, Feb. 25, 1927.

[2] *Comm. Phys. Lab.*, Leiden, No. 147 (1915).