



Philosophical Magazine Series 5

ISSN: 1941-5982 (Print) 1941-5990 (Online) Journal homepage: <http://www.tandfonline.com/loi/tphm16>

LXII. The physical basis of probability

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To cite this article: F.Y. Edgeworth M.A. (1883) LXII. The physical basis of probability , Philosophical Magazine Series 5, 16:102, 433-435, DOI: [10.1080/14786448308627459](https://doi.org/10.1080/14786448308627459)

To link to this article: <http://dx.doi.org/10.1080/14786448308627459>



Published online: 28 Apr 2009.



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The nature of the reaction between pure aqueous hydric sulphate and zinc is shown by our experiments to be of a very complicated character. Thus, from 58·77 to 79·62 there are two temperatures corresponding to every strength; and between strength 54·47 and 57·77 at least, there are four temperatures corresponding to every strength.

The law of relation of temperature to chemical change has hitherto been very little investigated. Hood and Warder, after some trial experiments, have regarded chemical effect as proportional to the square of the temperature. Our own representation places temperature on the footing of a chemical reagent.

Our work has had exclusive reference to the beginning of a chemical reaction; its object has been to find the initial line of no chemical change. There is, however, obviously a terminal zero-line, similarly obtainable, and related to the conditions existing at the close of a reaction. Between these two lines lies the surface, on which would occur all possible events in the actual process of change.

It is our intention to resume this investigation.

LXII. *The Physical Basis of Probability.* By F. Y. EDGEWORTH, M.A., *Lecturer on Logic at King's College, London*.*

A REMARKABLE analogy has been drawn by Donkin† between the behaviour of a material particle tending to equilibrium under the influence of attractive centres of various force, and the determination of the judgment to the "weighted mean" of several observations. The essential feature of the analogy is, according to the view of the present writer, the circumstance that mental as well as mechanical equilibrium is represented by a sum of squares. The expression

$$g_1(x_1 - x)^2 + g_2(x_2 - x)^2 + g_3(x_3 - x)^2 + \&c.$$

represents (twice) the potential energy of a dynamical system consisting of centres, at the points $x_1, x_2, \&c.$ along a line, of attractive force proportioned to the simple distance multiplied by $g_1, g_2, \&c.$ respectively. The same expression represents the disadvantage incurred by taking x as the real point from which the observations $x_1, x_2, \&c.$ of weights respectively $g_1, g_2, \&c.$ have diverged. But the representation in the latter case is not so faithful as in the former. The simple sum of squares is not the measure, but only the criterion, of the psychical quantity; decreasing as it decreases, and becoming

* Communicated by the Author.

† Ashmol. Soc. Trans. 1844; Liouville, *Journ. Math.* xv. (1850).
Phil. Mag. S. 5. Vol. 16. No. 102. Dec. 1883. 2 H

the least possible when it becomes the least possible, but not proportional to it. This sort of relation between psychical quantity and mathematical expression may be illustrated by the mathematical theory of exchange. There the forces at work, the tastes of the buyers and sellers, are of inconceivable complexity. Yet the position of equilibrium is characterized by a feature of geometrical simplicity, uniformity of rate-of-exchange. This possibility of mathematically representing maximum advantage is due to the same cause in the market as in the observatory: what may be called the law of great numbers. The sum of squares above written makes its appearance in virtue of the exponential law of error or probability-curve incidental to the Method of Least Squares; and this simple form arises when the observations are independent of each other and indefinitely* numerous. Similarly the law of unity of price holds good where the competitors are independent and indefinitely numerous. In both cases uniformity is due to plurality; definite order to infinite numbers.

It follows from this view that Donkin's representation of the *forces* of the intellectual machine is (except at the vanishing-point of equilibrium) nugatory. There is no correspondence between a force proportional to the simple distance and the mysterious pleasure-force which urges us to choose the most advantageous value. So, too, it would be easy to enhance the geometrical† representation of the field of competition by introducing the assumption that each economic atom is urged to objects of gratification according to some simple law of force. But the assumption would be destitute of scientific value.

The real point of union between the things compared by Donkin is the correspondence between the tendency of a mechanical system to maximum (kinetic, minimum potential) energy and the tendency of volition to maximum pleasure. This seems to be the physical basis of volition, and if so, of belief, with which, upon a plausible‡ theory, volition may almost be identified. No doubt it is difficult to refer all acts of will to one and the same law of maximum pleasure; it is not easy to refer some actions to any such law. It is difficult also to identify all the energy-principles of mathematical physics; and one of the most important (the Principle of Least Action) may seem to hold good only in cases of a certain simplicity—

* Infinite *relatively* to the limits of a single observation; as indicated in the postscript of the article on the Law of Error, *Phil. Mag.* Oct. 1883.

† The reader is referred here and throughout this note to the writer's essay on 'Mathematical Psychics' (Kegan Paul).

‡ Mr. Bain's.

between successive kinetic foci, in the absence of reflecting or refracting surfaces, and so forth. Nevertheless he who has realized the omnipresence and all-powerfulness of a maximum-principle in one form or another, both in the physical and the moral sciences, and who is persuaded of the harmony of those sciences, will not hastily abandon the conjecture that in the correspondence between maximum energy and greatest possible happiness is to be sought the first principle of Psycho-Physics.

LXIII. *On the Electromotive Force of Alloys.*

By JOHN TROWBRIDGE and E. K. STEVENS.*

THE best study of alloys and the most thorough work on them has been done by Matthiessen, who proved conclusively that alloys were neither mechanical mixtures nor chemical compounds, but what he terms, in a general way, "a solidified solution of one metal in another." He also showed that, with reference to the formation of alloys, metals were divided into two classes—the first class being those which, when alloyed with each other, give a conductivity in proportion to the respective volumes of the two metals; and the second those which, when alloyed with each other, give a conductivity which is less than that of the respective volumes of the two metals.

The aim of this investigation has been to note the variation of electromotive force in different alloys of the same metals and to deduce, if possible, some general law which governs the variation.

Two sets of alloys were used—one set of lead and tin, and the other of copper and zinc. The first set was made by taking the proportional weights of lead and tin, and melting them together in a crucible, and then pouring them out on a flat surface and allowing them to cool. The second set was made by melting a weighed amount of copper in a Fletcher gas-furnace, and, when in a molten state, adding more than the required amount of zinc, in order to make allowance for volatilization. Pure metals were obtained, in order that the results might be as accurate as possible.

It was deemed sufficient, as far as the lead and tin alloys were concerned, to weigh out carefully the required amounts of each metal, and to take those weights as showing the composition. This could not be done with the copper and zinc alloys, as it is impossible to determine how much of the zinc

* Proceedings of the American Academy of Arts and Sciences, vol. xviii. (May 29, 1883).