Letters to the Editor

CONCERNING THE ESTIMATE OF MEASUREMENT ERRORS

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Usp. Fiz. Nauk **85**, 391 (February, 1965)

ONE of the main tasks in making any kind of measurements is estimating the accuracy and reliability of the obtained results. It must be stated with regret that not only is insufficient attention paid to this task in instructing students, but in the majority of institutions preparatory to laboratory occupations the methods taught are outdated and unsatisfactory both in principle and from a practical point of view. To a considerable extent this is explained by the fact that the type of problems connected with the estimate of errors requires from the students a knowledge of the elements of mathematical analysis and the theory of probability. Nevertheless, it seems to us that this does not justify such a primitive approach to error estimate as found in the scientific literature. It is well known that the estimate of the random error of measurement requires, generally speaking, two numbers: the magnitude of the error and its corresponding confidence level. Instead of explaining the rules for finding these quantities for a small number of observations with the aid of suitable formulas and tables, it is common to limit oneself to a calculation of the mean arithmetical error and the so-called "limiting error," the metrological significance of which is not altogether clear in the case of random errors. Instead of the well-founded rule for adding variances, the students are usually taught to find the random error of a sum by adding the absolute values of the errors of the terms. It must be noted that with this rule for adding errors the error of the arithmetic mean turns out to be independent of the number of measurements and equal to the error of a single measurement. Thus the important rule for the decrease of the error of a result as $1/\sqrt{n}$, where n is the number of measurements, is not only unconfirmed but is in direct contradiction with the rule for adding errors. Nor is the question of the required number of measurements, determined by the ratio of random and systematic errors of the method, usually treated. As a result, student lose a great deal of time for error calculations and repeated measurements, failing to understand when one can restrict oneself to one measurement, and in which instances one must repeat measurements and how many times one must repeat them. Since in the majority of specialties the study of the theory of errors is restricted to what is taught in the physics laboratory in the first course, the rules learned there often serve later as the basis for calculating errors of practice as opposed to classroom measurements. One of the unpleasant consequences of this is the fact that it is often impossible to compare quantitative results of different investigations, because the methods for estimating the errors of one of the papers are completely unclear. This is particularly noticeable in cases in which a number is the main result of the research. In astronomical and geodesic measurements a strong tradition for careful error estimates has developed; in physical and physico-chemical investigations the situation is much worse, owing apparently in the main to the above deficiencies in the initial instruction. With all this, the basic assumptions of the theory of errors and the correct methods of error estimate can be discussed quite simply without use of mathematical apparatus inaccessible to beginners.

It appears to be of utmost importance to revise suitably the methods of teaching this chapter of the physics laboratory course.

Translated by Z. Barnea