A SIMPLE CALCULATION FOR ERGOGRAPHY

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In experiments using Mosso's ergograph, the calculation of the total work done involves a long and tedious measurement of the ordinates on the kymograph record. It is possible, no doubt, to use a mechanical counter fixed to the pulley or to the moving lever. This counter gives the excursions of the recording lever as the total distance or the height to which the mass has been lifted. In the absence of such a mechanical device a simple formula to determine the total distance is suggested and then the work done can easily be calculated.

The following mathematical solution needs only four measurements and thus considerably simplifies the calculations. Though an approximation this method is accurate enough for experimental purposes as well as for assessment of the progress in patients of myasthenia gravis.

If M is the mass used in the experiment, and if $h_1, h_2, h_3, \ldots\ldots h_n$ are the heights of the successive ordinates (displacements) the total work is given by :

$$W = Mgh_1 + Mgh_2 + Mgh_3 \ldots\ldots\ldots Mgh_n$$
$$W = Mg\,(h_1 + h_2 + h_3 \ldots\ldots\ldots h_n)$$
$$W = Mg\,\Sigma h$$

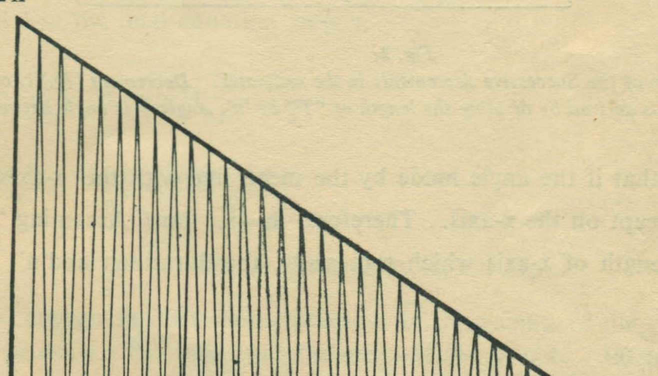

Fig. 1.

Schematic reproduction of an ergographic tracing. The three lines drawn are :
(1) *Hypotenuse touching all ordinates.* (2) *The base.* (3) *The first ordinate. The three measurements are*
(*i*) *The angle between the hypotensue and the base*
(*ii*) *The height of the first ordinate* (*iii*) *The number of ordinates. This is derived by the total length of the base i.e., time divided by intervals of ergographic recording.*

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For calculation a 'mean' line is drawn through the ends of the ordinates as shown in the figure 1. The ordinates touched by this line have successively decreasing heights the decrement being a constant. Let it be denoted by $\triangle$'h'.

It is obvious then that the successive heights constitute (numerically) an arthmetical progression. Now in an arithmetical progression of 'n' numbers with a common difference 'd' and the number which comes first i.e., the initial number 'a', the sum of all numbers is given by

$$S=\frac{n}{2} \quad 2a+(n-1)d$$

Hence, in the problem considered if h is the intitial displacement and there are 'n' displacements, the sum of the heights of all the ordinates is :

$$\Sigma h=\frac{n}{2} \quad 2h_1 \times (n-1) \quad h \ldots\ldots\ldots(1)$$

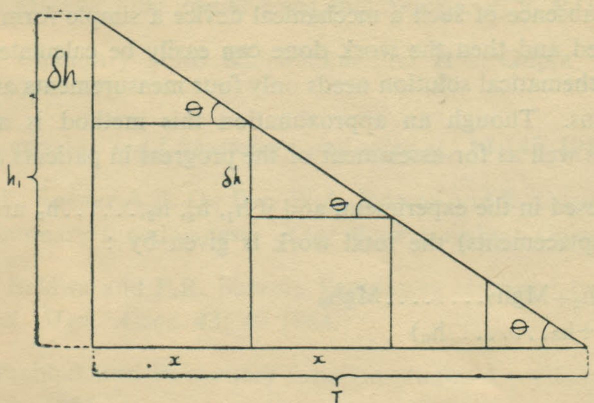

Fig. 2.

A graphic indication of the Successive decrements in the ordinates. Decrement ($\triangle$) is calculated as follows: $\triangle h=X.Tan\phi$ 'X' is derived by dividing the length of "T" by 'n'. Angle ϕ is angle between the hypotenuse and base.

In figure 2 it is seen that if the angle made by the mean line with the x-axis is ϕ, then ten $\frac{h}{x}$ where x is the intercept on the x-axis. Therefore $h=x. \tan\phi$ Assuming 'x' to be constant, $x\frac{T}{n}$ where T is the length of x-axis which represents the durationa and'n' the number of ordinates, we get,

$$\triangle h=\frac{T}{n} \quad \tan\theta.$$

Substituting the value of $\triangle$h in equation (1) we get :

$$\Sigma h=\frac{n}{2} \quad 2h_1+(n-1) \quad \frac{T}{n} \quad \tan\theta \ldots\ldots\ldots(2)$$

Since the progression is decreasing

$$\Sigma h=\frac{n}{2}\Big[\ 2h_1-(n-1) \quad \frac{T}{n}\tan\psi \quad \Big]\ldots\ldots\ldots(3)$$

Hence total work done is given by

$$W=Mg\frac{n}{2}\Big[\ 2h_1 \ -(n-1) \ \frac{T}{n} \ \tan\phi\Big] \text{ ergs.}$$

Note : (a) If final displacement is zero, then $\tan\phi=\frac{h_1}{T}$

WHENCE WE Obtain, $W=\frac{Mgh_1\ (1+n)/}{2}$

(b) If final displacement is not zero, (then as shown in figure 3, $\tan\phi=\frac{Y}{T}$; Whence,

$$W=\frac{Mgn}{2}\ \frac{2h_1\ -(n-1)y.}{2}$$

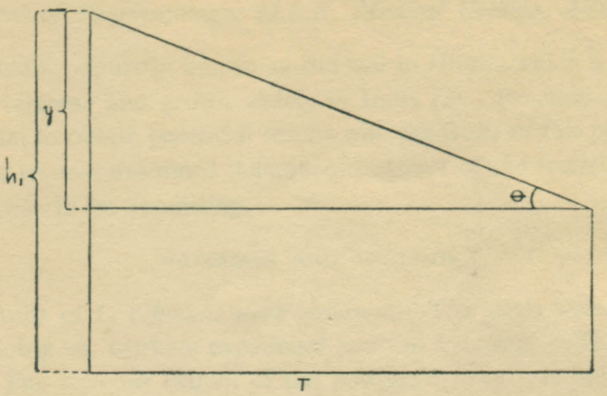

Fig. 3.

An incomplete Ergographic Record. The line drawn touching the tips of the ordinates does not meet the base line as in Fig. 1. A parallel line is drawn to 'T', the distance being the last ordinate.

Explanatory note for (a) If final displacement is zero then $\tan\phi=\frac{h_1}{T}$ Substituting this value of tan ϕ in the final equation we get,

$$W=Mg\ \frac{n}{2}\Big\}\ 2h_1\ -(n-1).\frac{T}{n}.\ \frac{h_1}{T}$$

$$=\frac{Mgn.h_1}{2}\cdot\frac{(1+n)}{n}=\frac{Mgh_1\,(1+n)}{2.}$$

EXPLANATION AND ELUCIDATION

The actual ergograph does show variations of the heights of the successive ordinates. It is expected that we draw a line indicating the mean of the heights. It will be seen that there are a number of ordinates above the line and a number of them below. When a straight line is drawan touching the ordinates it automatically means that the decrements are uniform or constant and the slope of the 'mean' line indicates the rate of decrement. Just as in other scattergrams a mean line inidcates the rate of change, here too it is assumed that the mean straight line indicates the decrements which are constant.

Actual comparison between the calculated results and measured results coincide to a high degree, hence the suggestion of this formula, which is quick and simple obviating the labourous process of measuring each ordinate with a divider or a scale.

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