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A MECHANICAL CALCULATOR TO SOLVE THE EQUATION

$$x = \frac{(d+z+c) \cdot y}{b+y} - c$$

ZABOJ V. HARVALIK

Mechanical calculators based upon equations that can be interpreted in terms of plane or spherical geometry are easily to construct and to operate. They mostly are precise enough for practical applications. The time of adjustment and calculation is very short, and therefore this kind of device will be welcome whenever time plays an important role.

The author constructed a mechanical calculator to solve the equation

$$x = \frac{(d+z+c) \cdot y}{b+y} - c \qquad (1)$$

by transforming the equation into a problem of plane geometry. These are the steps: If we consider that $(d+z+c)=a$ we obtain $x = \frac{a.y}{b+y} - c$. By multiplication of this equation with $(b+y)$ we obtain $x.(b+y)=a.y-c.(b+y)$ and transform to $x.b+x.y=a.y-c.b-c.y$. We continue the transformation: $x.b+c.b=a.y-x.y-c.y$ which can be written $(x+c).b=[a-(x+c)].y$. But this is the proportion $(x+c):y=[a-(x+c)]:b$ (2) concerning similar triangles as described in Fig. 1.

The triangles ABC and BDE are similar because they have the common vertex B and the sides ED and AC are parallel. Let ED= y, DF=c, FB=x, FG=z, GA=d, AC=b, and AD=a. From Fig. 1 it is evident that $(x+c):y=[a-(x+c)]:b$ (3), and that $a=d+z+c$ which establishes the relationship of the equation (1) and the proportion (2) which is identical with the proportion (3).

If we consider the terms b, c, and if necessary d constant, then z and y are conditional variables. We are able to calculate x if z and y are known.

Under these assumptions the calculator was designed and built. Fig. 2 shows a sketch of the calculator. The metal beam DA is perpendicular to the beam AC (=b=10 cm). At C is the pivot of the beam CE. Parallel to the beam AD is the slide DH with divisions from 0 cm to 45 cm (AF), and the distance c (=5 cm). A clip (at G) is held by a set screw on the beam AD at the distance d that can be varied from 20 cm to 40 cm in 2.5 cm intervals; the distance y is applied to the sliding beam CE along ED. To calculate the equation $x = \frac{(d+z+c).y}{b+y} - c$ we consider the distances c and b as absolutely constant, and adjust to the desired distance d by using the adjusting clip at G, and setting the mark on d (=20 cm, or e.g. 30 cm, etc.). Then the distance z is set on the slide HD so that the reading starts at F and continues toward H, at the clip (at G). If the distance y is applied to ED the intersection of the beam EC with the slide DH gives the distance x which is the solution of the equation.

TABLE I

1		2	3	4	5
d	z	x (estim.)	x (calc.)	Difference (Xc-Xe)	Error in percent
20	35	8.8	8.83	-0.03	-0.34
20	10	3.0	3.07	-0.07	-2.33
30	35	11.1	11.15	-0.05	-0.45
30	10	5.3	5.38	-0.08	-4.85
40	35	13.4	13.46	-0.06	-0.45
40	35	7.6	7.69	-0.09	-1.68

Consider: $b = 10$, $c = 5$, $y = 3$.

Table 1 shows a few solutions for x obtained by use of the calculator (see col. 2) and by evaluation of the equation (1) (see col. 3). Column 4 indicates the difference of read and evaluated x, and col. 5 shows the error in per cent. From col. 5 it is evident that the error is very small, and that it can be still decreased if the divisions on the slide DH are reduced to a fraction of a cm.

This calculator was especially designed to calculate the depth of foreign bodies (e.g. bullets or shell fragments, etc.) by X-rays. The determination of depth is based upon a parallactic method described in an excellent publication by Francis Blonek, M. D. "An Universal Table for Fluoroscopic Localisation of Foreign Bodies." Radiology, 38:172, 1942.

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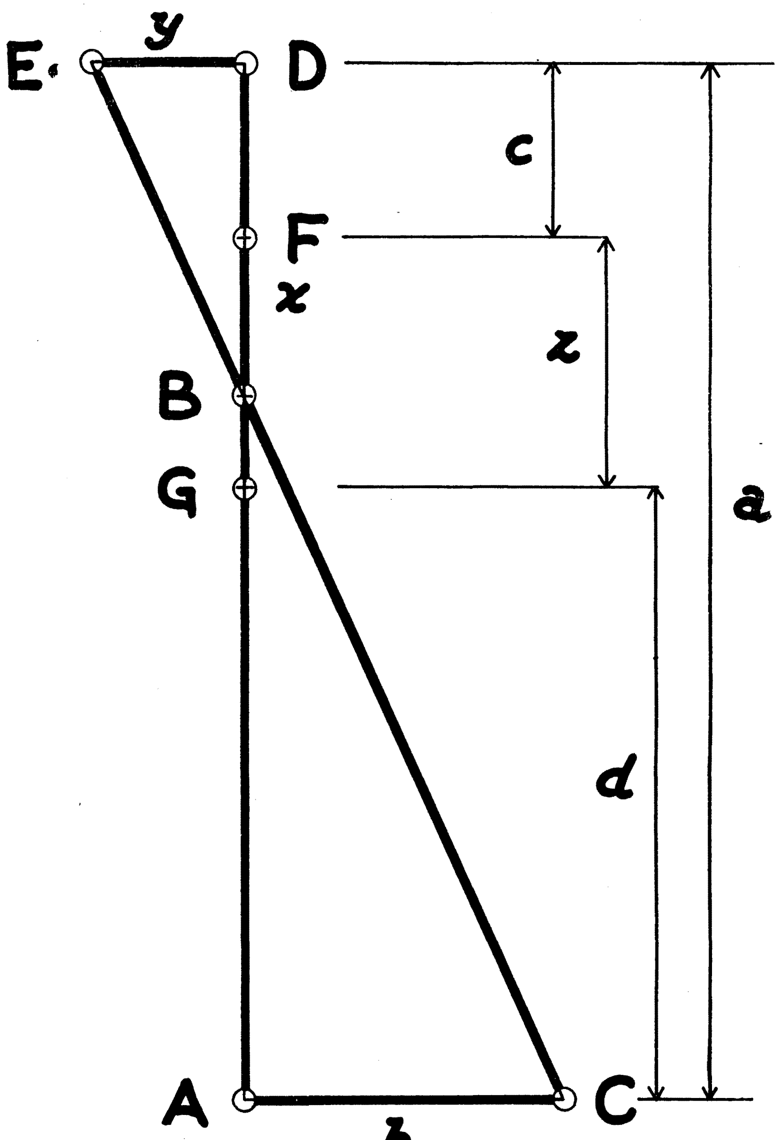

FIG. 1.

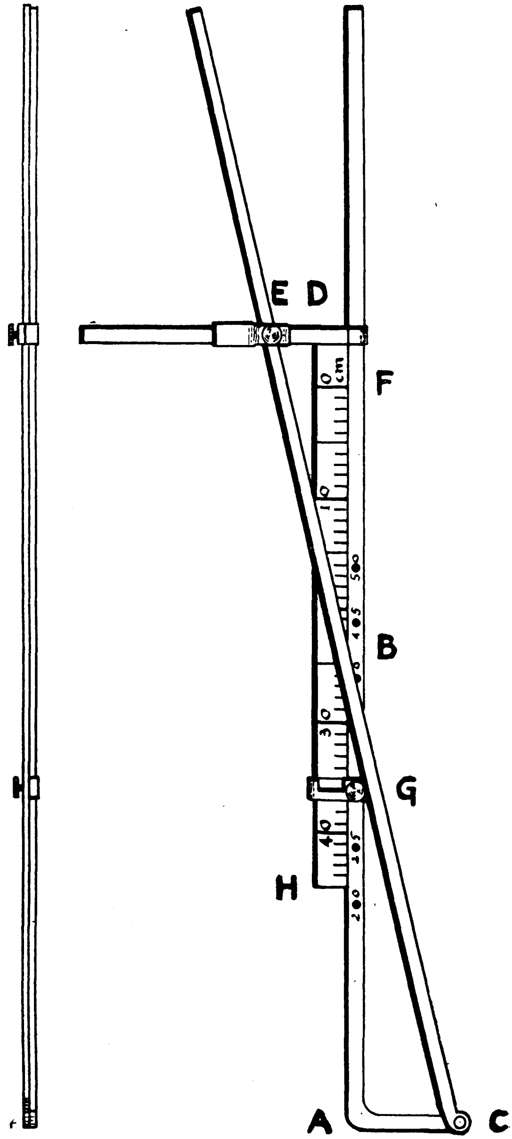

FIG. 2.