GRAPHICAL COMPUTING-TABLE

WILLIAM H. BIXBY

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THIS table (due to Lalanne, Inspector-General of Bridges and Highways, France) is composed principally of vertical lines, horizontal lines, and lines inclined thus ⟍, which last we will call "diagonals." The verticals and horizontals correspond to factors, the diagonals to products; the verticals and horizontals are numbered at their ends, the diagonals are numbered at their centre where they intersect the line inclined thus ⟋, and marked "squares." Other verticals, horizontals, and diagonals may be imagined intermediate to those drawn, and possessing numbers intermediate to those of the two nearest parallel lines. Thus the imagined vertical 1·75 will lie half way between the verticals 1·7 and 1·8; the imagined horizontal 3·68 will lie between the horizontals 3·6 and 3·7, and at a distance from the horizontal 3·6 equal to eight tenths of the total distance between the horizontals 3·6 and 3·7; the imagined diagonal 6·44 will lie between the diagonals 6·4 and 6·5, and at a distance from the diagonal 6·4 equal to four tenths of the total distance between diagonals 6·4 and 6·5.

The table is so constructed that any two factor lines intersect each other upon the diagonal denoting their product. Thus since $2 \times 5 = 10$, the vertical, numbered 2, intersects the horizontal, numbered 5, upon the diagonal, numbered 10.

The **errors** occasioned by the use of this table need **never exceed half of one per cent.**

RULES.

Multiplication.—Find the vertical and horizontal lines corresponding to the two given factors, find the diagonal of their intersection, and its number will be the required product.

Examples.—To multiply 1·75 by 3·68. Find the intersection of the imagined vertical 1·75 with the imagined horizontal 3·68; this imagined intersection will lie on the imagined diagonal 6·44, its number being taken, as above explained, where it cuts the line marked "squares."

To multiply 175 by 0·368. $175 = 1\cdot75 \times 100$; $0\cdot368 = 3\cdot68 \div 10$: Hence $175 \times 0\cdot368 = 1\cdot75 \times 100 \times 3\cdot68 \div 10 = 1\cdot75 \times 3\cdot68 \times 10$. Find, as before, $1\cdot75 \times 3\cdot68 = 6\cdot44$; multiply by 10, and we have $175 \times 0\cdot368 = 64\cdot4$.

Division.—Find the diagonal whose number (on the line of "squares") corresponds with the dividend, and the horizontal whose number corresponds with the divisor, then the vertical passing through their intersection will correspond with the quotient required, due regard being paid, as in the last example, to the correct position of the decimal point.

Examples.—To divide 6·44 by 3·68. Find the diagonal 6·44 and the horizontal 3·68; their intersection lies on the vertical 1·75. The required quotient is then 1·75.

To divide 64·4 by 0·368. $64\cdot4 \div 0\cdot368 = (6\cdot44 \times 10) \div (3\cdot68 \div 10) = 6\cdot44 \div 3\cdot68 \times 100$. Find, as before, $6\cdot44 \div 3\cdot68 = 1\cdot75$; then $64\cdot4 \div 0\cdot368 = 1\cdot75 \times 100 = 175\cdot0$.

Square.—Find where the vertical of the given number intersects the inclined line marked "**squares**;" find the diagonal of this intersection and take its value as given, on the line of "**squares,**" where this diagonal and the line of squares cut each other.

Example.—To find the square of 2. The vertical 2 intersects the line of squares at a point whose diagonal is numbered 4 where it cuts the line of squares. Hence $(2)^2 = 4$.

To find the square of 20. $(20)^2 = (2 \times 10)^2$: hence $(20)^2 = 2^2 \times 100$. Find, as before, $(2)^2 = 4$: multiply by 100, and we have $(20)^2 = 400$.

Square Root.—Reverse the operation for finding the square of a number.

Example.—To find the square root of 4·84. Look along the line of squares for the imagined point 4·84; the vertical through this point is 2·2. Hence $\sqrt{4 \cdot 84} = 2 \cdot 2$.

To find the square root of 484. $\sqrt{484} = \sqrt{(4 \cdot 84) \times (100)} = 10\sqrt{4 \cdot 84}$. Find, as above, $\sqrt{4 \cdot 84} = 2 \cdot 2$; multiply by 10, and we have $\sqrt{484} = 22$.

To find the square root of 0·0484. $\sqrt{0 \cdot 0484} = \sqrt{(4 \cdot 84) \div (100)} = \frac{1}{10} \sqrt{4 \cdot 84}$. Find, as before, $\sqrt{4 \cdot 84} = 2 \cdot 2$; divide by 10, and we have $\sqrt{0 \cdot 0484} = 0 \cdot 22$.

Cube.—Find where the vertical of the given number intersects the inclined line marked **"cubes;"** find the diagonal of this intersection and take its value as given, on the line of **"cubes,"** where this diagonal and the line of cubes cut each other.

Example.—To find the cube of 3. The vertical 3 intersects the lines of cubes at the point whose diagonal is numbered 27 where it cuts the line of cubes. Hence $(3)^3 = 27$. To find the cube of 30. $(30)^3 = (3 \times 10)^3 = (3)^3 \times (10)^3 = (3)^3 \times 1000$. Find, as before, $(3)^3 = 27$, and we have $(30)^3 = 27 \times 1000 = 27000$.

Cube Root.—Reverse the operation for finding the cube of any number.

Example.—To find the cube root of 10·65. Look along the line of cubes for the imagined point 10·65; the vertical through this point is 2·2. Hence $\sqrt[3]{10 \cdot 65} = 2 \cdot 2$.

To find the cube root of 10648.

$$\sqrt[3]{10648} = \sqrt[3]{(10 \cdot 648) \times (1000)} = 10 \sqrt[3]{10 \cdot 648}.$$

Find, as before, $\sqrt[3]{10 \cdot 65} = 2 \cdot 2$; multiply by 10, and we have $\sqrt[3]{10648} = 22$.

To find the cube root of 0·01065.

$$\sqrt[3]{0 \cdot 01065} = \sqrt[3]{(10 \cdot 65) \div (1000)} = \tfrac{1}{10} \sqrt[3]{10 \cdot 65}.$$

Find, as before, $\sqrt[3]{10 \cdot 65} = 2 \cdot 2$; divide by 10, and we have $\sqrt[3]{0 \cdot 01065} = 0 \cdot 22$.

Fifth Power.—Find where the vertical of the given number intersects the inclined line marked "**fifth power**;" find the diagonal of this intersection and take its value as given, on the line of "**fifth power**," where this diagonal and the line of fifth power cut each other.

Fifth Root.—Reverse the operation for finding the fifth power of any number.

Example.—To find the fifth root of 51·536. Look along the line of fifth power for the imagined point 51·5; the vertical through this point is 2·2. Hence $\sqrt[5]{51 \cdot 536}$ is 2·2.

To find the fifth root of 5153600.

$\sqrt[5]{5153600} = \sqrt[5]{(51 \cdot 536) \times (100000)} = 10\sqrt[5]{51 \cdot 536}$.

Find, as before, $\sqrt[5]{51 \cdot 5} = 2 \cdot 2$; multiply by 10, and we have $\sqrt[5]{5153600} = 22$.

To find the fifth root of 0·00051536.

$\sqrt[5]{0 \cdot 00051536} = \sqrt[5]{(51 \cdot 536) \div (100000)} = \frac{1}{10}\sqrt[5]{51 \cdot 536}$.

Find, as before, $\sqrt[5]{51 \cdot 5} = 2 \cdot 2$; divide by 10, and we have $\sqrt[5]{0 \cdot 00051536} = 0 \cdot 22$.

Circumference of Circle.—Find where the vertical, whose number is the radius of the given circle, intersects the horizontal line marked "*circumference of circle*;" find the diagonal of this intersection and take its value as given, on the line of "**squares,**" where this diagonal and the line of squares cut each other.

Area of Circle.—Find where the vertical, whose number is the radius of the given circle, intersects the inclined line marked "**area of circle**;" find the diagonal of this intersection and take its value as given, on the line of "**area of circle,**" where this diagonal and the line of area of circle cut each other.

Volume of Sphere.—Find where the vertical, whose number is the radius of the given sphere, intersects the inclined line marked "**volume of sphere**;" find the diagonal of this intersection and take its value as given, on the line of "**volume of sphere,**" where this diagonal and the line of volume of sphere cut each other.

Tangents and Cotangents.—The scales at the bottom of the table given the natural $\left\{\begin{matrix}\text{tangents}\\ \text{cotangents}\end{matrix}\right\}$ of arcs between $\left\{\begin{matrix}1^\circ \text{ and } 84^\circ\\ 89^\circ \text{ and } 6^\circ\end{matrix}\right\}$ and $\left\{\begin{matrix}96^\circ \text{ and } 179^\circ\\ 174^\circ \text{ and } 91^\circ\end{matrix}\right\}$.

To find the natural $\left\{\begin{matrix}\text{tangent}\\ \text{cotangent}\end{matrix}\right\}$ of any arc, look along the line marked $\left\{\begin{matrix}\text{tangent}\\ \text{cotangent}\end{matrix}\right\}$ for the nearest degree, pass to the next line, marked "subdivisions of arc," by means of which the position of the arc can be very closely located on the scale; comparing this position thus located with the numbers in the line marked "Numbers," the value of the $\left\{\begin{matrix}\text{tangent}\\ \text{cotangent}\end{matrix}\right\}$ required may be immediately read off.

Examples.—Tangent of $2° 7' = 0{\cdot}0368$. Tangent of $20° 15' = 0{\cdot}368$. Tangent of $74° 50' = 3{\cdot}68$.

The arcs are subdivided to every five minutes from tangent of 1° to tangent 10°, every ten minutes from tangent of 10° to tangent 20°, every fifteen minutes from tangent of 20° to tangent 60°, and every ten minutes from tangent of 60° to tangent 84°.

Sines and Cosines.—The scales at the top of the table give the natural $\left\{\begin{matrix}\text{sines}\\\text{cosines}\end{matrix}\right\}$ of arcs between $\left\{\begin{matrix}1° \text{ and } 90°\\89° \text{ and } 0°\end{matrix}\right\}$ and $\left\{\begin{matrix}90° \text{ and } 179°\\180° \text{ and } 91°\end{matrix}\right\}$.

To find the natural $\left\{\begin{matrix}\text{sine}\\\text{cosine}\end{matrix}\right\}$ of any arc, look along the line marked $\left\{\begin{matrix}\text{sines}\\\text{cosines}\end{matrix}\right\}$ for the nearest degree, pass to the next line marked "subdivisions of arc" by means of which the position of the arc can be closely located on the scale; comparing this position thus located with the numbers in the line marked "Numbers," the value of the $\left\{\begin{matrix}\text{sine}\\\text{cosine}\end{matrix}\right\}$ required may be immediately read off.

Examples.—Sine of $2° \ 7' = 0{\cdot}0368$. Sine of $21° \ 40' = 0{\cdot}368$.

The arcs are subdivided to every five minutes from sine 1° to sine 10°, every ten minutes from sine 10° to sine 20°, every fifteen minutes from sine 20° to sine 30°, every thirty minutes from sine 30° to sine 50°, every degree from sine 50° to sine 70°, every two degrees from sine 70° to sine 80°, and every five degrees from sine 80° to sine 90°.

N. B. When the $\left\{ \begin{array}{c} \text{sine} \\ \text{cosine} \end{array} \right\}$ or $\left\{ \begin{array}{c} \text{tangent} \\ \text{cotangent} \end{array} \right\}$ is to be used as a factor, it is not necessary to obtain its numerical value, but only to notice its position upon the scale of natural numbers. It is for this purpose of ready comparison that the scales of sines, cosines, tangents, and cotangents are put directly above and below the table.

Metres into Feet.—Find where the vertical, whose number denotes the given number of feet, intersects the dotted horizonal line marked "*Metres into Feet*;" find the diagonal of this intersection and take its value as given on the line of **squares** where this diagonal and the line of squares cut each other.

Feet into Metres.—Reverse the operation just described.

N. B. Whenever any number is to be used many times as a factor, much time will be saved if its position be marked on the table, either by drawing this line clear across the table as is the value of $2\pi = 6{\cdot}28$ for the "circumference of circle," or by drawing an arrow —> on the side of the table in prolongation of the corresponding line as is done in the case of "Metres into Feet;" in the latter case the name of the line can be written on its prolongation, and the line itself need not be drawn across the table.

TABLES

TO ACCOMPANY

GRAPHICAL COMPUTING-TABLE.

PROPERTIES OF REGULAR POLYGONS.

No. of Sides.	Name.	Area when diameter of inscribed circle is unity.	Area when side is unity.	Length of side when radius of inscribed circle is unity.	Radius of inscribed circle when side is unity.	Radius of circumscribed circle when side is unity.	Length of side when radius of circumscribed circle is unity.
3	Triangle.......	1·299	0·433	3·464	0·289	0·577	1·732
4	Square.	1·000	1·000	2·000	0·500	0·707	1·414
5	Pentagon......	0·908	1·720	1·453	0·688	0·851	1·176
6	Hexagon......	0·866	2·598	1·155	0·866	1·000	1·000
7	Heptagon......	0·843	3·634	0·963	1·039	1·152	0·868
8	Octagon.......	0·828	4·828	0·828	1·207	1·307	0·765
9	Nonagon......	0·819	6·182	0·728	1·374	1·462	0·684
10	Decagon.......	0·812	7·694	0·650	1·539	1·618	0·618
11	Undecagon....	0·807	9·366	0·587	1·703	1·775	0·563
12	Dodecagon....	0·804	11·196	0·536	1·866	1·932	0·518

TABLE OF ELEMENTARY BODIES, WITH THEIR ATOMIC WEIGHTS AND SPECIFIC GRAVITY.

NAME.	Symbol.	Atomic Weight.	Specific Gravity.
Aluminium................	Al.	27·4	2·6
Antimony (Stibium)........	Sb.	122·0	6·7
Arsenic..................	As.	75·0	5·7
Barium	Ba.	137·0	4·0
Beryllium (Glucinum)......	Be.	9·4	2·1
Bismuth..................	Bi.	210·0	9·8
Boron....................	B.	11·0	...
Bromine	Br.	80·0	2·96
Cadmium..................	Cd.	112·0	8·6
Cæsium...................	Cs.	133·0	...
Calcium..................	Ca.	40·0	1·6
Carbon { Diamond / Graphite }....	C.	12·0	{ 3·5 / 2·3 }
Cerium	Ce.	92·0	5·5
Chlorine	Cl.	35·5	1·3
Chromium	Cr.	52·2	7·3
Cobalt...................	Co.	58·8	8·5
Copper (Cuprum)...........	Cu.	63·4	8·9
Didymium	D.	95·0	...
Erbium...................	E.	112·6	...
Fluorine.................	F.	19·0	...
Gallium	Ga.	68·0	...
Gold (Aurum)..............	Au.	197·0	19·3
Hydrogen.................	H.	1·0	...
Indium...................	In.	113·4	7·2
Iodine	I.	127·0	4·9
Iridium..................	Ir.	198·0	22·4
Iron (Ferrum).............	Fe.	56·0	7·7
Lanthanum................	La.	93·6	...
Lead (Plumbum)............	Pb.	207·0	11·4
Lithium..................	Li.	7·0	0·6
Magnesium................	Mg.	24·0	1·7

NAME.	Symbol.	Atomic Weight.	Specific Gravity.
Manganese	Mn.	55·0	7·0
Mercury (Hydrargyrum)	Hg.	200·0	13·6
Molybdenum	Mo.	96·0	8·6
Nickel	Ni.	58·8	8·3
Niobium	Nb.	94·0	7·0
Nitrogen	N.	14·0	...
Osmium	Os.	199·2	21·4
Oxygen	O.	16·0	...
Palladium	Pd.	106·6	11·7
Phosphorus	P.	31·0	1·9
Platinum	Pt.	197·4	21·5
Potassium (Kalium)	K.	39·1	0·9
Rhodium	Rh.	104·4	11·2
Rubidium	Rb.	85·4	1·5
Ruthenium	Ru.	104·4	11·2
Selenium	Se.	79·4	4·8
Silicium	Si.	28·0	2·5
Silver (Argentum)	Ag.	108·0	10·4
Sodium	Na.	23·0	1·0
Strontium	Sr.	87·6	2·5
Sulphur	S.	32·0	2·0
Tantalum	Ta.	182·0	10·5
Tellurium	Te.	128·0	6·2
Thallium	Tl.	204·0	11·8
Thorinum	Th.	235·0	7·7
Tin (Stannum)	Sn.	118·0	7·2
Titanium	Ti.	50·0	...
Tungsten (Wolfram)	W.	184·0	17·4
Uranium	U.	240·0	18·4
Vanadium	V.	51·2	5·5
Yttrium	Y.	61·7	...
Zinc	Zn.	65·2	6·8
Zirconium	Zr.	89·6	4·1

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