seat, originally acquired by the state in 1795. Louis Bonaparte, king of Holland, who was very fond of the spot, formed a zoological collection here which was removed to Amsterdam in 1809. In 1816 the estate was presented by the nation to the prince of Orange (afterwards King William II.) in recognition of his services at the battle of Quatre Bras. Since then the palace and grounds have been considerably enlarged and beautified. Close to Baarn in the south-west were formerly situated the ancient castles of Drakenburg and Drakenstein, and at Vuursche there is a remarkable dolmen.

BABADAG, or BABATAG, a town in the department of Tulcea, Rumania; situated on a small lake formed by the river Taitza among the densely wooded highlands of the northern Dobrudja. Pop. (1900) about 3500. The Taitza lake is divided only by a strip of marshland from Lake Razim, a broad landlocked sheet of water which opens on the Black Sea. Babadag is a market for the wool and mutton of the Dobrudja. It was founded by Bayezid I., sultan of the Turks from 1389 to 1403. It occasionally served as the winter headquarters of the Turks in their wars with Russia, and was bombarded by the Russians in 1854.

BABBAGE, CHARLES (1792–1871), English mathematician and mechanician, was born on the 26th of December 1792 at Teignmouth in Devonshire. He was educated at a private school, and afterwards entered St Peter's College, Cambridge, where he graduated in 1814. Though he did not compete in the mathematical tripos, he acquired a great reputation at the university. In the years 1815–1817 he contributed three papers on the "Calculus of Functions" to the *Philosophical Transactions*, and in 1816 was made a fellow of the Royal Society. Along with Sir John Herschel and George Peacock he laboured to raise the standard of mathematical instruction in England, and especially endeavoured to supersede the Newtonian by the Leibnitzian notation in the infinitesimal calculus. Babbage's attention seems to have been very early drawn to the number and importance of the errors introduced into astronomical and other calculations through inaccuracies in the computation of tables. He contributed to the Royal Society some notices on the relation between notation and mechanism; and in 1822, in a letter to Sir H. Davy on the application of machinery to the calculation and printing of mathematical tables, he discussed the principles of a calculating engine, to the construction of which he devoted many years of his life. Government was induced to grant its aid, and the inventor himself spent a portion of his private fortune in the prosecution of his undertaking. He travelled through several of the countries of Europe, examining different systems of machinery; and some of the results of his investigations were published in the admirable little work, *Economy of Machines and Manufactures* (1834). The great calculating engine was never completed; the constructor apparently desired to adopt a new principle when the first specimen was nearly complete, to make it not a difference but an analytical engine, and the government declined to accept the further risk (see CALCULATING MACHINES). From 1828 to 1839 Babbage was Lucasian professor of mathematics at Cambridge. He contributed largely to several scientific periodicals, and was instrumental in founding the Astronomical (1820) and Statistical (1834) Societies. He only once endeavoured to enter public life, when, in 1832, he stood unsuccessfully for the borough of Finsbury. During the later years of his life he resided in London, devoting himself to the construction of machines capable of performing arithmetical and even algebraical calculations. He died at London on the 18th of October 1871. He gives a few biographical details in his *Passages from the Life of a Philosopher* (1864), a work which throws considerable light upon his somewhat peculiar character. His works, pamphlets and papers were very numerous; in the *Passages* he enumerates eighty separate writings. Of these the most important, besides the few already mentioned, are *Tables of Logarithms* (1826); *Comparative View of the Various Institutions for the Assurance of Lives* (1826); *Decline of Science in England* (1830); *Ninth Bridgewater Treatise* (1837); *The Exposition of 1851* (1851).

See *Monthly Notices, Royal Astronomical Society*, vol. 32.

BABEL, the native name of the city called Babylon (*q.v.*) by the Greeks, the modern *Hillah*. It means "gate of the god," not "gate of the gods," corresponding to the Assyrian *Bāb-ili*. According to Gen. xi. 1-9 (J), mankind, after the deluge, travelled from the mountain of the East, where the ark had rested, and settled in Shinar. Here they attempted to build a city and a tower whose top might reach unto heaven, but were miraculously prevented by their language being confounded. In this way the diversity of human speech and the dispersion of mankind were accounted for; and in Gen. xi. 9 (J) an etymology was found for the name of Babylon in the Hebrew verb *bālal*, "to confuse or confound," Babel being regarded as a contraction of Balbel. In Gen. x. 10 it is said to have formed part of the kingdom of Nimrod.

The origin of the story has not been found in Babylonia. The tower was no doubt suggested by one of the temple towers of Babylon. W. A. Bennet (*Genesis*, p. 169; cf. Hommel in Hastings' *Dictionary of the Bible*) suggests E-Saggila, the great temple of Merodach (Marduk). The variety of languages and the dispersion of mankind were regarded as a curse, and it is probable that, as Prof. Cheyne (*Encyclopaedia Biblica*, col. 411) says, there was an ancient North Semitic myth to explain it. The event was afterwards localized in Babylon. The myth, as it appears in Genesis, is quite polytheistic and anthropomorphic. According to Cornelius Alexander (frag. 10) and Abydenus (frags. 5 and 6) the tower was overthrown by the winds; according to Yaqut (i. 448 f.) and the Lisan el-'Arab (xiii. 72) mankind were swept together by winds into the plain afterwards called "Babil," and were scattered again in the same way (see further D. B. Macdonald in the *Jewish Encyclopaedia*). A tradition similar to that of the tower of Babel is found in Central America. Xelhua, one of the seven giants rescued from the deluge, built the great pyramid of Cholula in order to storm heaven. The gods, however, destroyed it with fire and confounded the language of the builders. Traces of a somewhat similar story have also been met with among the Mongolian Tharus in northern India (*Report of the Census of Bengal*, 1872, p. 160), and, according to Dr Livingstone, among the Africans of Lake Ngami. The Esthonian myth of "the Cooking of Languages" (Kohl, *Reisen in die Ostseeprovinzen*, ii. 251-255) may also be compared, as well as the Australian legend of the origin of the diversity of speech (Gerstäcker, *Reisen*, vol. iv. pp. 381 seq.).

BAB-EL-MANDEB (Arab. for "The Gate of Tears"), the strait between Arabia and Africa which connects the Red Sea (*q.v.*) with the Indian Ocean. It derives its name from the dangers attending its navigation, or, according to an Arabic legend, from the numbers who were drowned by the earthquake which separated Asia and Africa. The distance across is about 20 m. from Ras Menheli on the Arabian coast to Ras Siyan on the African. The island of Perim (*q.v.*), a British possession, divides the strait into two channels, of which the eastern, known as the Bab Iskender (Alexander's Strait), is 2 m. wide and 16 fathoms deep, while the western, or Dact-el-Mayun, has a width of about 16 m. and a depth of 170 fathoms. Near the African coast lies a group of smaller islands known as the "Seven Brothers." There is a surface current inwards in the eastern channel, but a strong under-current outwards in the western channel.

BABENBERG, the name of a Franconian family which held the duchy of Austria before the rise of the house of Habsburg. Its earliest known ancestor was one Poppo, who early in the 9th century was count in Grapfeld. One of his sons, Henry, called margrave and duke in Franconia, fell fighting against the Normans in 886; another, Poppo, was margrave in Thuringia from 880 to 892, when he was deposed by the German king Arnulf. The family had been favoured by the emperor Charles the Fat, but Arnulf reversed this policy in favour of the rival family of the Conradines. The leaders of the Babenbergs were the three sons of Duke Henry, who called themselves after their castle of Babenberg on the upper Main, round which their possessions centred. The rivalry between the two families was intensified by their efforts to extend their authority in the region of the middle Main, and this quarrel, known as the "Babenberg feud," came to a head at the beginning of the 10th century during the crystallizing in monoclinic prisms, and occurring in various natural waters, as an efflorescence in limestone caverns, and in the neighbourhood of decaying nitrogenous organic matter. Hence its synonyms, "wall-saltpetre" and "lime-saltpetre"; from its disintegrating action on mortar, it is sometimes referred to as "saltpetre rot." The anhydrous nitrate, obtained by heating the crystallized salt, is very phosphorescent, and constitutes "Baldwin's phosphorus." A basic nitrate, $Ca(NO_3)_2 \cdot Ca(OH)_2 \cdot 3H_2O$, is obtained by dissolving calcium hydroxide in a solution of the normal nitrate.

Calcium phosphide, Ca_3P_2, is obtained as a reddish substance by passing phosphorus vapour over strongly heated lime. Water decomposes it with the evolution of spontaneously inflammable hydrogen phosphide; hence its use as a marine signal fire ("Holmes lights"), (see L. Gattermann and W. Haussknecht, *Ber.*, 1890, 23, p. 1176, and H. Moissan, *Compt. Rend.*, 128, p. 787).

Of the calcium orthophosphates, the normal salt, $Ca_3(PO_4)_2$, is the most important. It is the principal inorganic constituent of bones, and hence of the "bone-ash" of commerce (see PHOSPHORUS); it occurs with fluorides in the mineral apatite (*q.v.*); and the concretions known as coprolites (*q.v.*) largely consist of this salt. It also constitutes the minerals ornithite, $Ca_3(PO_4)_2 \cdot 2H_2O$, osteolite and sombrerite. The mineral brushite, $CaHPO_4 \cdot 2H_2O$, which is isomorphous with the acid arsenate pharmacolite, $CaHAsO_4 \cdot 2H_2O$, is an acid phosphate, and assumes monoclinic forms. The normal salt may be obtained artificially, as a white gelatinous precipitate which shrinks greatly on drying, by mixing solutions of sodium hydrogen phosphate, ammonia, and calcium chloride. Crystals may be obtained by heating di-calcium pyrophosphate, $Ca_2P_2O_7$, with water under pressure. It is insoluble in water; slightly soluble in solutions of carbonic acid and common salt, and readily soluble in concentrated hydrochloric and nitric acid. Of the acid orthophosphates, the mono-calcium salt, $CaH_4(PO_4)_2$, may be obtained as crystalline scales, containing one molecule of water, by evaporating a solution of the normal salt in hydrochloric or nitric acid. It dissolves readily in water, the solution having an acid reaction. The artificial manure known as "superphosphate of lime" consists of this salt and calcium sulphate, and is obtained by treating ground bones, coprolites, &c., with sulphuric acid. The di-calcium salt, $Ca_2H_2(PO_4)_2$, occurs in a concretionary form in the ureters and cloaca of the sturgeon, and also in guano. It is obtained as rhombic plates by mixing dilute solutions of calcium chloride and sodium phosphate, and passing carbon dioxide into the liquid. Other phosphates are also known.

Calcium monosulphide, CaS, a white amorphous powder, sparingly soluble in water, is formed by heating the sulphate with charcoal, or by heating lime in a current of sulphuretted hydrogen. It is particularly noteworthy from the phosphorescence which it exhibits when heated, or after exposure to the sun's rays; hence its synonym "Canton's phosphorus," after John Canton (1718–1772), an English natural philosopher. The sulphydrate or hydrosulphide, $Ca(SH)_2$, is obtained as colourless, prismatic crystals of the composition $Ca(SH)_2 \cdot 6H_2O$, by passing sulphuretted hydrogen into milk of lime. The strong aqueous solution deposits colourless, four-sided prisms of the hydroxy-hydrosulphide, Ca(OH)(SH). The disulphide, CaS_2, and pentasulphide, CaS_5, are formed when milk of lime is boiled with flowers of sulphur. These sulphides form the basis of Balmain's luminous paint. An oxysulphide, $2CaS \cdot CaO$, is sometimes present in "soda-waste," and orange-coloured, acicular crystals of $4CaS \cdot CaSO_4 \cdot 18H_2O$ occasionally settle out on the long standing of oxidized "soda- or alkali-waste" (see ALKALI MANUFACTURE).

Calcium sulphite, $CaSO_3$, a white substance, soluble in water, is prepared by passing sulphur dioxide into milk of lime. This solution with excess of sulphur dioxide yields the "bisulphite of lime" of commerce, which is used in the "chemical" manufacture of wood-pulp for paper making.

Calcium sulphate, $CaSO_4$, constitutes the minerals anhydrite (*q.v.*), and, in the hydrated form, selenite, gypsum (*q.v.*), alabaster (*q.v.*), and also the adhesive plaster of Paris (see CEMENT). It occurs dissolved in most natural waters, which it renders "permanently hard." It is obtained as a white crystalline precipitate, sparingly soluble in water (100 parts of water dissolve 24 of the salt at 15° C.), by mixing solutions of a sulphate and a calcium salt; it is more soluble in solutions of common salt and hydrochloric acid, and especially of sodium thiosulphate.

Calcium silicates are exceptionally abundant in the mineral kingdom. Calcium metasilicate, $CaSiO_3$, occurs in nature as monoclinic crystals known as tabular spar or wollastonite; it may be prepared artificially from solutions of calcium chloride and sodium silicate. H. Le Chatelier (*Annales des mines*, 1887, p. 345) has obtained artificially the compounds: $CaSiO_3$, Ca_2SiO_4, $Ca_3Si_2O_7$, and Ca_3SiO_5. (See also G. Oddo, *Chemisches Centralblatt*, 1896, 228.) Acid calcium silicates are represented in the mineral kingdom by gyrolite, $H_2Ca_2(SiO_3)_3 \cdot H_2O$, a lime zeolite, sometimes regarded as an altered form of apophyllite (*q.v.*), which is itself an acid calcium silicate containing an alkaline fluoride, by okenite, $H_2Ca(SiO_3)_2 \cdot H_2O$, and by xonalite $4CaSiO_3 \cdot H_2O$. Calcium silicate is also present in the minerals: olivine, pyroxenes, amphiboles, epidote, felspars, zeolites, scapolites (*qq.v.*).

Detection and Estimation.—Most calcium compounds, especially when moistened with hydrochloric acid, impart an orange-red colour to a Bunsen flame, which when viewed through green glass appears to be finch-green; this distinguishes it in the presence of strontium, whose crimson coloration is apt to mask the orange-red calcium flame (when viewed through green glass the strontium flame appears to be a very faint yellow). In the spectroscope calcium exhibits two intense lines—an orange line (α), (λ 6163), a green line (β), (λ 4229), and a fainter indigo line. Calcium is not precipitated by sulphuretted hydrogen, but falls as the carbonate when an alkaline carbonate is added to a solution. Sulphuric acid gives a white precipitate of calcium sulphate with strong solutions; ammonium oxalate gives calcium oxalate, practically insoluble in water and dilute acetic acid, but readily soluble in nitric or hydrochloric acid. Calcium is generally estimated by precipitation as oxalate which, after drying, is heated and weighed as carbonate or oxide, according to the degree and duration of the heating.

CALCULATING MACHINES. Instruments for the mechanical performance of numerical calculations, have in modern times come into ever-increasing use, not merely for dealing with large masses of figures in banks, insurance offices, &c., but also, as cash registers, for use on the counters of retail shops. They may be classified as follows:—(i.) Addition machines; the first invented by Blaise Pascal (1642). (ii.) Addition machines modified to facilitate multiplication; the first by G. W. Leibnitz (1671). (iii.) True multiplication machines; Léon Bollés (1888), Steiger (1894). (iv.) Difference machines; Johann Helfrich von Müller (1786), Charles Babbage (1822). (v.) Analytical machines; Babbage (1834). The number of distinct machines of the first three kinds is remarkable and is being constantly added to, old machines being improved and new ones invented; Professor R. Mehmke has counted over eighty distinct machines of this type. The fullest published account of the subject is given by Mehmke in the *Encyclopädie der mathematischen Wissenschaften*, article "Numerisches Rechnen," vol. i., Heft 6 (1901). It contains historical notes and full references. Walther von Dyck's *Catalogue* also contains descriptions of various machines. We shall confine ourselves to explaining the principles of some leading types, without giving an exact description of any particular one.

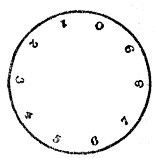

FIG. 1.

Practically all calculating machines contain a "counting work," a series of "figure disks" consisting in the original form of horizontal circular disks (fig. 1), on which the figures 0, 1, 2, to 9 are marked. Each disk can turn about its vertical axis, and is covered by a fixed plate with a hole or "window" in it through which one figure can be seen. On turning the disk through one-tenth of a revolution this figure will be changed into the next higher or lower. Such turning may be called a "step," *positive* if the next higher and *negative* if the next lower figure appears. Each positive step therefore adds one unit to the figure under the window, while two steps add two, and so on. If a series, say six, of such figure disks be placed side by side, their windows lying in a row, then any number of six places can be made to appear, for instance 000373. In order to add 6425 to this number, the disks, counting from right to left, have to be turned 5, 2, 4 and 6 steps respectively. If this is done the sum 006798 will appear. In case the sum of the two figures at any disk is greater than 9, if for instance the last figure to be added is 8 instead of 5, the sum for this disk is 11 and the 1 only will appear. Hence an arrangement for "carrying" has to be introduced. This may be done as follows. The axis of a figure disk contains a wheel with ten teeth. Each figure disk has, besides, one long tooth which when its 0 passes the window turns the next wheel to the left, one tooth forward, and hence the figure disk one step. The actual mechanism is not quite so simple, because the long teeth as described would gear also into the wheel to the right, and besides would interfere with each other. They must therefore be replaced by a somewhat more complicated arrangement, which has been done in various ways not necessary to describe more fully. On the way in which this is done, however, depends to a great extent the durability and trustworthiness of any arithmometer; in fact, it is often its weakest point. If to the series of figure disks arrangements are added for turning each disk through a required number of steps,

Addition machines.

same as five (or less) turns of the handle, and more than two pushes are never required.

Multiplication machines. The *Steiger-Egli* machine is a multiplication machine, of which fig. 3 gives a picture as it appears to the manipulator. The lower part of the figure contains, under the covering plate, a carriage with two rows of windows for the figures marked *ff* and *gg*. On pressing down the button W the carriage can be moved to right or left. Under each window is a figure disk, as in the Thomas machine. The upper part has three

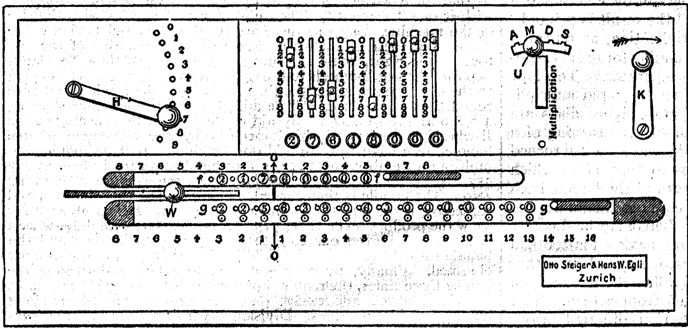

FIG. 3.

sections. The one to the right contains the handle K for working the machine, and a button U for setting the machine for addition, multiplication, division, or subtraction. In the middle section a number of parallel slots are seen, with indices which can each be set to one of the numbers 0 to 9. Below each slot, and parallel to it, lies a shaft of square section on which a toothed wheel, the A-wheel, slides to and fro with the index in the slot. Below these wheels again lie 9 toothed racks at right angles to the slots. By setting the index in any slot the wheel below it comes into gear with one of these racks. On moving the rack, the wheels turn their shafts and the figure disks *gg* opposite to them. The dimensions are such that a motion of a rack through 1 cm. turns the figure disk through one "step" or adds 1 to the figure under the window. The racks are moved by an arrangement contained in the section to the left of the slots. There is a vertical plate called the multiplication table block, or more shortly, the *block*. From it project rows of horizontal rods of lengths varying from 0 to 9 centimetres. If one of these rows is brought opposite the row of racks and then pushed forward to the right through 9 cm., each rack will move and add to its figure disk a number of units equal to the number of centimetres of the rod which operates on it. The block has a square face divided into a hundred squares. Looking at its face from the right—*i.e.* from the side where the racks lie—suppose the horizontal rows of these squares numbered from 0 to 9, beginning at the top, and the columns numbered similarly, the 0 being to the right; then the multiplication table for numbers 0 to 9 can be placed on these squares. The row 7 will therefore contain the numbers 63, 56, . . . 7, 0. Instead of these numbers, each square receives two "rods" perpendicular to the plate, which may be called the units-rod and the tens-rod. Instead of the number 63 we have thus a tens-rod 6 cm. and a units-rod 3 cm. long. By aid of a lever H the block can be raised or lowered so that any row of the block comes to the level of the racks, the units-rods being opposite the ends of the racks.

The action of the machine will be understood by considering an example. Let it be required to form the product 7 times 385. The indices of three consecutive slots are set to the numbers 3, 8, 5 respectively. Let the windows *gg* opposite these slots be called *a*, *b*, *c*. Then to the figures shown at these windows we have to add 21, 56, 35 respectively. This is the same thing as adding first the number 165, formed by the units of each place, and next 2530 corresponding to the tens; or again, as adding first 165, and then moving the carriage one step to the right, and adding 253. The first is done by moving the block with the units-rods opposite the racks forward. The racks are then put out of gear, and together with the block brought back to their normal position; the block is moved sideways to bring the tens-rods opposite the racks, and again moved forward, adding the tens, the carriage having also been moved forward as required. This complicated movement, together with the necessary carrying, is actually performed by one turn of the handle. During the first quarter-turn the block moves forward, the units-rods coming into operation. During the second quarter-turn the carriage is put out of gear, and moved one step to the right while the necessary carrying is performed; at the same time the block and the racks are moved back, and the block is shifted so as to bring the tens-rods opposite the racks. During the next two quarter-turns the process is repeated, the block ultimately returning to its original position. Multiplication by a number with more places is performed as in the Thomas. The advantage of this machine over the Thomas in saving time is obvious. Multiplying by 817 requires in the Thomas 16 turns of the handle, but in the Steiger-Egli only 3 turns, with 3 settings of the lever H. If the lever H is set to 1 we have a simple addition machine like the Thomas or the Brunsviga. The inventors state that the product of two 8-figure numbers can be got in 6–7 seconds, the quotient of a 6-figure number by one of 3 figures in the same time, while the square root to 5 places of a 9-figure number requires 18 seconds.

Machines of far greater powers than the arithmometers mentioned have been invented by Babbage and by Scheutz. A description is impossible without elaborate drawings. The following account will afford some idea of the working of Babbage's difference machine. Imagine a number of striking clocks placed in a row, each with only an hour hand, and with only the striking apparatus retained. Let the hand of the first clock be turned. As it comes opposite a number on the dial the clock strikes that number of times. Let this clock be connected with the second in such a manner that by each stroke of the first the hand of the second is moved from one number to the next, but can only strike when the first comes to rest. If the second hand stands at 5 and the first strikes 3, then when this is done the second will strike 8; the second will act similarly on the third, and so on. Let there be four such clocks with hands set to the numbers 6, 6, 1, 0 respectively. Now set the third clock striking 1, this sets the hand of the fourth clock to 1; strike the second (6), this puts the third to 7 and the fourth to 8. Next strike the first (6); this moves the other hands to 12, 19, 27 respectively, and now repeat the striking of the first. The hand of the fourth clock will then give in succession the numbers 1, 8, 27, 64, &c., being the cubes of the natural numbers. The numbers thus obtained on the last dial will have the differences given by those shown in succession on the dial before it, their differences by the next, and so on till we come to the constant difference on the first dial. A function

$$y = a + bx + cx^2 + dx^3 + ex^4$$

gives, on increasing x always by unity, a set of values for which the fourth difference is constant. We can, by an arrangement like the above, with five clocks calculate y for $x = 1, 2, 3, \ldots$ to any extent. This is the principle of Babbage's difference machine. The clock dials have to be replaced by a series of dials as in the arithmometers described, and an arrangement has to be made to drive the whole by turning one handle by hand or some other power. Imagine further that with the last clock is connected a kind of typewriter which prints the number, or, better, impresses the number in a soft substance from which a stereotype casting can be taken, and we have a machine which, when once set for a given formula like the above, will automatically print, or prepare stereotype plates for the printing of, tables of the function without any copying or typesetting, thus excluding all possibility of errors. Of this "Difference engine," as Babbage called it, a part was finished in 1834, the government having contributed £17,000 towards the cost. This great expense was chiefly due to the want of proper machine tools.

Meanwhile Babbage had conceived the idea of a much more powerful machine, the "analytical engine," intended to perform any series of possible arithmetical operations. Each of these was to be communicated to the machine by aid of cards with holes punched in them into which levers could drop. It was long taken for granted that Babbage left complete plans; the committee of the British Association appointed to consider this question came, however, to the conclusion (*Brit. Assoc. Report*, 1878, pp. 92-102) that no detailed working drawings existed at all; that the drawings left were only diagrammatic and not nearly sufficient to put into the hands of a draughtsman for making working plans; and "that in the present state of the design it is not more than a theoretical possibility." A full account of the work done by Babbage in connexion with calculating machines, and much else published by others in connexion therewith, is contained in a work published by his son, General Babbage.

Slide rules. Slide rules are instruments for performing logarithmic calculations mechanically, and are extensively used, especially where only rough approximations are required. They are almost as old as logarithms themselves. Edmund Gunter drew a "logarithmic line" on his "Scales" as follows (fig. 4):—On a line AB lengths are set off to scale to represent the common logarithms of the numbers 1 2 3 . . . 10, and the points thus obtained are marked with these numbers.