THE LATEST EDITION, CONSIDERABLY ENLARGED.

THE

HAWTHORN

LOCOMOTIVE ENGINEERS'

SLIDE RULE,

ITS HISTORY AND USE.

PUBLISHED BY

JOHN RABONE & SONS,

MANUFACTURERS, BY STEAM MACHINERY,

OF

Boxwood, Ivory, & Steel Rules,

ENGINE DIVIDED STEEL STRAIGHT EDGES,

WITH VARIOUS GRADUATIONS;

MEASURING TAPES,

WITH STEEL, METALLIC WIRE, OR LINEN TAPES.

SPIRIT LEVELS, &c.

HOCKLEY ABBEY WORKS, BIRMINGHAM.

Established 1784.—The oldest House in the Trade.

PRICE—SIXPENCE.

[ENTERED AT STATIONERS' HALL.]

HALL & ENGLISH, PRINTERS, HIGH STREET, BIRMINGHAM.

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THE HAWTHORN
LOCOMOTIVE ENGINEERS' SLIDE RULE.

OF THE SLIDE RULE IN GENERAL.

Many kinds of Slide Rules are in use under different names, as Routledge's, the Carpenter's Rule, Hawthorn's, or the Locomotive Engineers' Rule, Hoare's, and others, but they are all constructed upon one general principle, and show results by the same unerring law, the only differences in them being, that each kind is adapted to suit the particular special purpose to which it is intended to be applied.

The Hawthorn's, or Locomotive Engineers' Slide Rule, is in the form of one of the earliest made, called Coggleshall's, and the four lines which constitute the working parts are precisely the same as that known as "the Carpenter's" Rule. It has obtained the name of "Hawthorn's," from its having been selected by Robert Hawthorn, one of the principals of the great engineering works at Newcastle-upon-Tyne, for the use of their mechanics, and contains tables specially arranged by him for their requirements.

Of all the tools and implements in daily use by mechanics, none is more frequently in the hand of the workman than the Slide Rule; but, nevertheless, a very small proportion of those who use it for the inches, &c., upon it, as a measure of length, have any idea of the deep mathematical principles involved in its construction, and of the important uses, in making calculations, to which it may be applied. Small as is the knowledge of it in our own country, in which it was invented, it is less known and less used upon the Continent, though of late in some of the French Colleges, the use of the Slide Rule is systematically taught. A French writer upon mathematics, three quarters of a century ago, said, "in England the use of the Sliding Rule was taught in all the schools at the same time with the letters of the alphabet,"—a statement which, it is needless to say, must be taken with more than the usual grain of reservation, and which is as near the truth as are some of the statements of the French regarding English manners and customs at the present day. One writer has said of it, and truly so, that "for a few shillings most persons may put into their pockets many hundred times as much power of calculation as they have in their heads; for the use of the instrument is attainable without any knowledge of the properties of logarithms on which it is constructed."

Before proceeding to explain the working of the Slide Rule by examples, it may be well to give a short history of its invention, and the steps by which it has attained its present form: also a few instances of its applicability to the calculations usually required by mechanics, from which it will be seen to be an instrument capable of performing mechanically, all the problems which are to be solved by the science of arithmetic. The labour of manipulating long series of figures for nautical and astronomical purposes, besides the uncertainty of their being true without laborious checking, led Mr. Babbage, in our own day, to the construction of his marvellous machines, which will work out any series of abstruse calculations for which they have been arranged, as the Jacquard loom weaves any required pattern for which it is set. One of the earliest attempts, however, to facilitate calculation, by mechanical means, was made more than two hundred and fifty years ago by Baron Napier, of Merchiston, in Scotland; and as this attempt was the precursor of the Sliding Rule, we will, in a brief manner, show somewhat of what it was. The invention

Fig. 1

Fig. 2

consisted of a number of flat bone or ivory rods, one of which was called the "index rod," marked as Fig. 1, and also at least ten others—one for each of the digits, headed at top with its own digit. We give a representation in Fig. 2 of one of the rods belonging to the number 4. It will be seen that the figures below the head-line 4 are all multiples of that number, as 8, 12, 16, 20, and so on, to 36, and the figures may be *read* in that way, though in calculation they are *used* rather differently. The other nine rods were constructed in similar manner, each containing multiples of the figure at the head, except the one with a cypher, which was filled up entirely with cyphers. One index rod is sufficient, but as many of each of the other rods are required in the operations as are contained in the multiplicand, or the figure to be multiplied. Thus, to multiply 382145 by another number:—against the "index rod," placed at the left hand, is to be laid to the right of it, one headed 3, against that an 8, a 2, a 1, a 4, and a 5. The seven rods all lying side by side, the topmost, or heading, line would read across thus:—1382145. The unit of the multiplier is found on the index rod, and on the same line from across the other rods, a line of figures is deduced by addition, and the same process being followed for each figure in the multiplier, a series of figures is obtained which, added together, gives the answer. Division was effected in a somewhat similar manner but even with those aids, arithmetical calculations were tedious operations. It was not that the "rods" were esteemed because of their saving much labour, for they did not do so; but it was that from the simplicity of the operation, more accurate results were likely to be obtained than by the ordinary methods of multiplying and dividing. From the circumstance of the rods being made of bone or ivory, they were called "Napier's bones," and they have been more frequently noticed in historical works than in those relating to their use. It is a singular circumstance that so well-informed a writer as Sir Walter Scott was, should have written of them without knowing what the phrase meant, as was evidently the case, when he made David Ramsay, in *The Fortunes of Nigel*, swear by "the bones of the immortal Napier."

But though Napier's bones did not prove of much help to science, the invention of them was the forerunner of what, to mathematicians, has proved an inestimable advantage—the invention of logarithms. It would be altogether beyond our present purpose to show minutely the construction of logarithms, but it may be briefly said that they are a series of numbers in arithmetical progression, which correspond to others in geometrical progression, by means of which arithmetical calculations can be made with much more ease and expedition than by the old method.

The immense labour of large and frequently-repeated multiplications, divisions, and the extractions of roots in the construction of trigonometrical and other tables, led Baron Napier, from the invention of the "bones," to a more thorough investigation of the subject, and thus the almost useless, but, nevertheless, curious, invention of the one, led the way to the invaluable discovery of the other.

The relation of logarithms to natural numbers may be explained by two series of numbers—the one (the logarithms) being in an arithmetical, and the other (the natural numbers) being in a geometrical, progression, thus:—

Logarithms	0	1	2	3	4	5	6	7	8
Nat. Numbers	1	2	4	8	16	32	64	128	256

By the aid of logarithms, the addition of two logarithmic numbers has the same effect as the more laborious process of multiplication; and subtraction, the same as division by the common method; for multiplication and division are only repeated additions and subtractions performed in another way. Taking the upper line of the above figures, if we *add* 3 and 5 together, we get 8, the natural number of which is 256—exactly the same result as if 8 and 32, the natural numbers, had been *multiplied* together. Or for division: in the upper line take 2 from 8 which leaves 6, and under 6 is the natural number 64, the quotient, or the result of dividing the natural number 256 by 4. Again, if it be required to involve 4 as high as the 4th power, multiply 2, the number which stands over 4, by the "index" of the power to which the number is to be involved, which is 4; the product 8, standing over 256, shows that this last number is the fourth power of 4, or $4 \times 4 \times 4 \times 4$ sought. Further: to extract the cube root of 64: Divide the number 6, which stands over 64, by 3, the index of the root to be extracted, and the quotient 2, standing over 4, shows 4, the root required. In these examples the saving of labour is scarcely appreciable, but the innumerable lengthy processes for obtaining numbers in a series, which would have to be resorted to, were it not for the aid of logarithms, would have been made with great labour, and the compilation of such frequently issued books as the *Nautical Almanac*, and kindred works would have been well nigh impossible.

The invention of logarithms was looked upon by the learned as the great discovery of the age. Mr. Briggs, it is recorded, was "beside himself with joy," and Kepler, the astronomer royal, "looked upon it as a miracle." Napier's discovery was not, like those of Kepler and Newton, connected with any analogies or coincidences which might naturally have led him to it, but was the result of unassisted reason and science; and, says his biographer, "we shall be vindicated in placing him in one of the very highest niches in the temple of fame. Kepler," he goes on to say, "had made many unsuccessful attempts to discover his canon for the periodic movements of the planets, and Newton had applied the palpable tendency of heavy bodies to the earth to the system of the universe in general; but Napier wrought out his admirable rules, by a slow scientific process arising from the gradual evolution of truth."

The radix or root, now called the base, from which Napier started, being found to be an inconvenient one, Mr. Henry Briggs, Mathematical Reader at Gresham College, in the year 1615, and shortly after Napier's invention, adopted the number 10 as being preferable, and on this basis logarithms have since been constructed. Mr. Briggs's system was, therefore thus:—

Logarithms	0	1	2	3	4	5	6
Natural Numbers in Geom'cal Progression	1	10	100	1,000	10,000	100,000	1,000,000

Thus 2 is the logarithm of 100, because $10 \times 10 = 100$, and 3 of 1,000, because $10 \times 10 \times 10 = 1{,}000$.

By this brief sketch, we are now brought to notice the lines which form the Sliding Rule, and the ones above and below, by means of which calculations are made. It is needful, however, to premise that the graduations upon it being in *tens, or multiples of tens*, it will be needful that the student should have some knowledge of *decimal fractions* and the mode of reading them. For this purpose any elementary work on decimals may be consulted.

In the ordinary decimal scale of figures, the value of any one of the nine digits—or figures—decreases in a tenfold degree for each place that it advances to the right hand. Thus, in the number 333, the 3 to the right represents 3 only, while the next 3 represents 30, and the other figure to the left hand represents 300. Now, if we assume that this law of ten-fold decrease holds good to the right hand of the place of units, we shall have the advantage of being able to deal with fractions, in the same way as with whole numbers.

Thousands.	Hundreds.	Tens	Unit	Tenths.	Hundredths.	Thousandths.
4	3	2	1	2	3	4

It will be only necessary in writing whole numbers, together with fractions of this kind, to be certain which figure is meant to stand in the place of units; and then, the place of each of the figures to the right of that, will determine its own relative value of magnitude. It is usual to put a full point or a comma—a full point is preferable—after the figure occupying the unit's place. This indicates that all the figures to the left of it are ordinary whole numbers, and all to the right of it are decimal fractions.

Thus 24·3 means 2 tens 4 units and 3 tenths.
·54 means 5 tenths and 4 hundredths.
·006 means 6 thousandths.

The advantage derived from this law, regulating the value of the digits, is very great; for by it, we are enabled to deal with *the most minute fractions* with as much ease as with whole numbers.

The addition of any number of cyphers to the right hand of a decimal fraction does not in any way alter its value, for whether we write ·5 ·50 or ·500 the same value is expressed, viz., five-tenths, fifty-hundredths, or five-hundred-thousandths, which is equivalent to the vulgar fraction expressed by ½ (half). But if we place a cypher *before* the other figures, and instead of ·50 write ·050, we alter the value of every successive figure; the tenths have become changed to hundredths, the hundredths have become thousandths, and the value of the whole fraction has been *decreased* ten-fold. In whole numbers therefore, the addition of cyphers *at the right hand* increases their value ten-fold for every cypher so added, but with the fractions of decimals it does not affect their value at all.

In the early part of the seventeenth century, Edmund Gunter, an English mathematician, and also Professor at Gresham College, invented the sector, and several other very useful mathematical instruments, and the surveyors' chain of 100 links for land measuring. He it was, who first conceived the idea of marking out, on a scale, spaces according to the logarithmic value of numbers placed over against them. In addition to those other scales upon the sector for lines, tangents &c., laid down in this way, he invented what he called the "line of numbers," which is the same as that now used upon the sliding rule.

FIG. 3

In Fig. 3 we have Gunter's logarithmic line of numbers. Assuming that the space from the 1 at the left to the 1 at the right is divided into 1000 equal parts, it may be seen that so many of those equal parts are allotted to each number as is represented by the logarithm of that number. We give a table of logarithms from 1 to 10 :—

Number.	Logarithm.
1	·0
2	·301
3	·477
4	·602
5	·698
6	·778
7	·845
8	·903
9	·954
10	1·000

and each of the logarithms represents as many parts of the thousand as they occupy of the spaces from the 1 to itself. All the subdivisions are, of course, logarithmic also.

In order to prove how the addition of logarithms is equivalent to the multiplication of common numbers, take the following example :—

	Natural Numbers.		Logarithms.
Multiply	2	the logarithm of which is	·301
by	4	the logarithm of which is	·602
		the product of which is	
	8	the logarithm of which is	·903

the same result as the addition of ·301 and ·602

Lest the student, adding, from the above table, the logarithms of 5 and 2 together, may find the result to be ·999 instead of 1·000 the logarithm of 10, it may be noted that that is owing to the fractions not being carried out to as many places of decimals as is needful. The exact

logarithm of 5 is ·698970 and the exact
" " 2 is ·301030 which added together,

give the result 1·000000, or 1 the logarithm of 10.

This logarithmic scale, or Gunter's line, was not at first used with another similar one sliding against it, as is now the case, but operations were performed on it by the application of a pair of compasses, adding or subtracting, as multiplication or division was required. The figures upon it are all of arbitrary value. If we call the first 1 one, then shall we read the next figure 2, and so on ; but if the first 1 is called 10, then the 2 will be 20, and so on to the end; and so with all the intermediate divisions likewise. If the 1 in the middle be read as 1 or unity, then the first 1, being but a tenth of it must be read as a fraction, ·1, the first 2 as ·2 and so on. It may interest the learner to see how the scale was at first used with compasses.

To multiply 15 by 4 by means of the compasses see Fig. 3, page 6. Calling the first figure 10, then extend the compasses from thence to the fifth division, which is 15 (half between the 10 and 20). *Add* this space, by placing one leg of the compasses at the figure 4, and the other leg will be found to extend to the 6, which, as the 1 was called 10, must rank as 60, the product of 15 multiplied by 4.

Division was effected in a reverse manner. To divide 60 by 4: set the compasses at 6 or 60, and extend them backwards to the 4. Then, with this radius, on applying them to the first end—1 on the scale—they will be found to extend to 15, the quotient. In all the examples easy numbers are chosen, for simplicity, and to enable the learner the more readily to understand the methods employed.

For convenience in practice, a second line of numbers is usually placed after the first (see Fig. 4, page 8) the latter half being ten-fold the value of the first one, and this plan has since been always adopted. It may be stated that this addition of the same radius may be made to any extent, each one increasing in value ten times the preceding one. By this arrangement, higher values are shown, which in the case of only a single radius would lie beyond the end of the scale, and another advantage gained by it is, that the fractions are shown on a greater scale than would be possible if the line were made too comprehensive. This addition of radii might be continued, as remarked, to any extent, but the two are found sufficient for usual operations.

We give a few other examples with the compasses to enable the learner the better *to see with the eye* how operations were performed.

To find the product of two numbers, or to multiply them, see Fig. 4. From 1 extend the compasses to the multiplier; and the same extent, applied the same way from the multiplicand, will reach the product. Thus if the product of 4 and 8 be required, extend the compasses from 1 to 4, and that extent, laid from 8, the same way will reach to 32, their product.

To divide one number by another, see Fig. 4. The extent of space on the logarithmic scale, from the divisor to unity will reach from the dividend to the quotient. Thus to divide 36 by 4: extend the compasses from 4 to 1, and the same extent applied backwards will reach from 36 to 9, the quotient sought.

To three given numbers to find a fourth proportional, see Fig. 4 Suppose the numbers to be 6, 8, 9; extend the compasses from 6 to 8, and this extent laid from 9 the same way, will reach to 12, the fourth proportional required.

Fig. 4

To find a mean proportional between any two given numbers, see Fig. 4. Between 8 and 32: Extend the compasses from 8, on the left hand part of the line, to 32 on the right; then bisecting this distance, its half will reach from 8 forward, or from 32 backward, to 16, the mean proportional sought.

To extract the square root of any number, see Fig. 4. Suppose it to be 25. Bisect the distance between 1 on the scale and the point representing 25; then the half of this distance set off from 1, will give the point representing the root 5. In the same manner the cube root, or the root of any higher power, may be found by dividing the distance on the line between 1 and the given number into as many equal parts as the index of the power expresses; then one of those parts, set from 1, will reach the point representing the root required.

It can readily be conceived that the use of the scale by the application of compasses was both tedious and troublesome. A few years after its invention, the Rev. William Oughtred, an eminent mathematician, adopted the plan of placing one ruler against another and sliding them together, as might be required, and hence the term "sliding rule." He was a man who set little value upon instrumental aids, unless in the hands of those who had previously learned the principles on which they were constructed. A pupil of his, William Forster, says, that in the year 1630, he spoke to Mr. Oughtred of a Gunter's ruler he had, 6 feet long, to be used with a pair of beame compasses; upon which he (W. Oughtred) answered that "the use of the compasses was a poor invention, and the performance very troublesome. But," said he to Forster, "seeing you are taken with such mechanical wayes of instruments, I will show you what devices I have had by mee these many yeares; and first he brought mee two rulers of that sort, to be used by applying one to the other without any compasses; and after that he showed mee those lines cast into a circle or ring, with another movable circle upon it." Mr. Forster then goes on to speak of the "great expediteness of both of those wayes, but especially of the latter, wherein it farre excelleth any other instrument which hath bin knowne." Circular logarithmic scales—the one working over and upon the other, have been, and continue to be, made to the present time, of both brass and cardboard; but while a long line can be obtained by a circle of 12 inches diameter, it has its disadvantages, a chief one being that a continual and wearisome turning about of the instrument is required, to obtain an upright reading of the scale.

A writer who, in composing a work on astronomy, made use of both the circular and the straight line, says, "the circular lines gave the measurements more accurately than the rule did, but a straight wooden rule of the same radius (as large a one) would have done quite as well, and would have been more convenient."

The inconvenience of having two separate "scales" or "rulers" being soon found, they were then attached together by brass clips; and presently afterwards the slide in a groove, as we now have it, was devised by a Mr. Everard. This method of sliding one scale against another, rendered the use of the compasses no longer necessary, but the slide may be considered as a pair of compasses already set to any extent. We have thought well, however, to a clear understanding of the lines, to show somewhat at length the method followed when compasses were the only means employed.

It may be supposed that at first the sliding rule was not much used, if only from the difficulties found in its construction. This may be judged of from the following extract from the interesting diary of Mr. Pepys, secretary to the Admiralty in the time of Charles II. Under the date of the 10th August, 1664, Pepys says:—"Abroad to find out one to engrave my tables upon my new sliding rule with silver plates, it being so small that Browne, that made it, cannot get one to do it. So I got Cocker,* the famous writing master, to do it, and I set an hour beside him to see him design it all; and strange it is to see him, with his natural eyes, to cut so small at his first designing it, and read it all over, without any missing, when, for my life, I could not, with my best skill, read one word or letter of it." To this entry Pepys adds, the next day, "Comes Cocker, with my rule, which he hath engraved to admiration for goodness and smallness of work; it cost me 14s. the doing."

The prices of those days were high, as compared with those of our own time, when for a few shillings a rule may be obtained doubtless of greater accuracy, and in a more convenient form than was then charged (14s.) for merely marking the divisions of the slide.

Nor was the difficulty inconsiderable in obtaining "good rules," nearly a century later, for in 1755, when James Watt, the great improver of the steam engine, was at work in London as a rule maker, he wrote to his father that "it was a most difficult matter to get rules good, there being only one man who could make them perfectly well, and he had lately taken to other work." Watt found his first employment in London under Mr. John Morgan, of Finch Lane, Cornhill, of whom he wrote, "though he works chiefly in the brass way, he can teach me most branches of the business, such as rules, scales, quadrants, &c." In less than two months after his arrival in London, Watt writes that "he had made a brass parallel rule, 18 inches long, and a brass scale of the

* The famous arithmetician and writing master, whose name has given to the language the proverbial saying, "According to Cocker."

same length." By December "he could work tolerably well, and he expected that by April he would understand so much of his business as to be able to work for himself." When June had again come round, and within twelve months of his first attempt at rule making, Watt wrote to his father in Glasgow, that he "could now make a brass sector, with a French joint, which is reckoned as nice a piece of framing work as is in the trade."

Apropos to the subject, Watt's "garret" at Heathfield Hall, near Birmingham, has been made widely known by Dr. Smiles's description of it in his charming *Lives of Boulton and Watt*. It is not now our purpose to notice how that fine old man James Watt spent his last years in inventing his ingenious copying machines, by which wood, stone, or metals could be fashioned after any model, which in America, and later on at Enfield, have been so successfully applied in accurately and cheaply fashioning gun stocks and materials—nor the machines themselves, which still remain at Heathfield, and which Messrs. John Rabone and Sons have so well applied to the manufacture of rules; his foot lathe, upon which till a few years ago were lying the veritable chips and turnings as the great master had left them fifty years before; the crucibles of metal and stone; the bottles of chemicals; the boxes of fossils and minerals; blow pipes and thermometers of many kinds, all made by his own hand; the now universally-used letter-copying press which he invented, and the bottle of now dried-up ink which he devised for its use, with many of the ingredients of which it was composed; his jar of snuff, with the thick coating of dust upon it; his frying-pan and Dutch-oven, coated with grease, exactly as he left it half a century ago; his screws, punches, taps, and dies—but to notice the drawers on the left-hand side of the room, in which were, and are still, stowed away many of the tools with which he worked in the early part of his life. These contain some articles which it is evident he set great store by, as they are, most of them, wrapped up and labelled, with his remarks upon their excellence or special qualities. One of these drawers contains his old "flute tools," and in another is the "brass sector with a French joint," carefully wrapped up in paper by his own hands. It is a fine piece of work, and shows no appearance of having ever been used; and it is perhaps not unsafe to say that it was preserved as a sample of his early work, of which he so proudly wrote to his father; for in the same drawer are various other tools, such as are used in the marking of rules by hand at the present day. These, although valueless in themselves, were evidently treasured with great care, many of them are carefully labelled, and were doubtless from time to time viewed with both pride and pleasure by their owner, as they have been by the writer of these lines. By the one, that he had given up the making of "brass sectors with French joints," and "other rules," to acquire fame and fortune for himself, and to benefit the world by his improvements of the steam engine—by the other, in the consideration of the honour it is to the craft of rule-making, that James Watt found in it an outlet for his early ingenuity, and made work which cannot be excelled in the present day. It may be interesting to know that the sliding rule long used by this great man was, till lately preserved in Birmingham, and was used as a check in testing calculations. Is it not more than probable that this rule may be the handiwork of its former great and famous possessor?

It appears that the first rule makers were to be found only in London; but, after a time, the trade extended to Wolverhampton and Birmingham. The *Birmingham Daily Post*, in a trade article some years ago, says, "the rule trade was originally a Wolverhampton one, and a century ago the greater part of the rules produced were made there. Fifty years ago, however, there were but seven employers remaining in Wolverhampton, and now not a single maker is left in that town. With the exception of a small quantity made in London, the whole trade is now located in Birmingham. But like so many other manufactures, that of rule making has been revolutionized by the adaptation of steam machinery to its requirements. Since its introduction, now more than forty years ago, by Messrs. Rabone and Sons, of the Hockley Abbey Works, Birmingham, the trade has assumed a different character. Prior to that time it was, to a great extent, carried on by little makers, who worked 'by hand,' but the advent of machinery may be broadly said to have swept them from the field of competition. Not only is many times the former 'out-put' now made, but the number of employers has been considerably reduced, not being more than one-fourth of what it then was; and notwithstanding the increased supply by means of the application of machinery and many automatic processes, the number of operatives is ten times greater than it was before, and the wages earned are much higher than could have been afforded when everything depended upon hand labour."

OF THE HAWTHORN'S LOCOMOTIVE ENGINEERS' SLIDE RULE.

We have already described the primitive method of using the logarithmic line of numbers by compasses, before the plan of placing a sliding piece between two others was invented, and will now proceed to describe the particulars and some of the uses of the slide rule which is specially known as "Hawthorn's." It is so named because some of the data marked upon it were laid down and first applied to the rule by Mr. Robert Hawthorn, one of the celebrated firm of makers of locomotive engines at Newcastle-upon-Tyne. It will be seen on looking at the rule that the slide with the lines above it and below, are marked A, B, C, and D. The lines A, B, and C are all alike. The A line may be considered as the original logarithmic line of a double radius as shewn in Fig 4, page 8; the B line as, or rather instead of, the moveable compassess formerly used against it; and the C line (exactly the same), as a pair of compasses against the D line. The D line is, however, different from the others. Although logarithmic, as they all are, it is of a double radius: where the C line counts by hundreds, the D line counts by tens, and therefore, any number on the C line always has its square root on D, but this will be particularly explained further on. The A, B, and C lines are the same in the Hawthorn's rule, the ordinary carpenter's rule, and the Routledge rule, but in the latter one the D line runs from 1 to 10, and in the two former it commences at 4 and runs on to 40, or the figures may be read as 40 to 400, &c. This is so arranged to bring the number 12, which is a frequent gauge point in measuring, near the centre of the slide that problems may be the more readily worked out by the lines C and D. In using the Routledge rule the figure 12, which is frequently required, lies near the end of the line which is not so convenient. The D line is used in all questions in which cubic or solid measure is required to be estimated, and is sometimes called the line of squares, because twice the logarithm of any number is equal to the logarithm of its square.

The other face of the rule is marked with inches, divided into eighths and sixteenths. It contains several tables; the first next the joint shows the Direct Cohesion of Bars, one inch square; the second gives the Transverse Strength of Beams, one inch square and twelve inches in length, and these two tables show the greatest weight the bars and beams will bear before breaking. From the second table it appears that a beam of cast iron, one inch square and twelve inches long, loaded on the centre, will safely bear 860 lbs. with a deflection of 1-40th part of an inch, which data may be assumed for common joists in buildings, &c. The third table is one of Specific Gravities of several substances in frequent use; the fourth is one of Lineal Measures; the fifth Square Measure; and the sixth Cubic Measure, with the weight and measure of Coals at Newcastle and London. Each edge of the rule contains scales, one divided into 12ths and the other into 10ths.

On another part of the rule is the slide and lines of numbers, with a table of Gauge Points, or Divisors, for squares, cylinders, and globes; for the weight and strength of ropes, chains, and iron; regular polygons; steam engine governors; the properties of the circle; the power of high pressure engines; and the temperature of steam at different pressures, &c.

NUMERATION.

How to read the Rule.

The first point of importance in the practical use of the Slide Rule is to well understand the values of the figures and divisions upon it. These are all arbitrary. The logarithmic line may therefore be of any length, and yet of equal value, the only difference being that the greater length to which it is extended, the more distinct will be the fractional parts of which it is composed. The reading of the Slide Rule is the great difficulty to beginners. Take the rule in hand, and note (in the lines A, B, and C, which are all alike) they are *figured* from 1, 2, 3, 4, &c., up to 1, and onwards 2, 3, 4, &c., again to 10. If the first 1 at the left be considered a unit, then the 1 in the middle will represent 10, and the 10 at the extreme right 100. Or the first 1 may represent ·1, then will the middle 1 be unity, and the 10 at the right hand will be really 10. The second radius (from the middle to the right) is always ten times the value of the first radius; and so on, if radius after radius were added to the extreme right, each additional one would be ten times the value of that preceding. A useful plan for the student to test the correctness of his reading is to draw out the slide till 1 on B is under some easily defined number on A, and then to write down the numbers on A over any given numbers on B. Thus, if 1 on the slide B is set under 21 on A, the figures will read :—

A	21	31·5	42	52·5	63	73·5	84	94·5	105	115·5	126
B	1	1·5	2	2·5	3	3·5	4	4·5	5	5·5	6

It will be seen that each line keeps its own numeration, and with the same ratio of increase; for as 1 on B is to 21 on A, so is 2 to 42, 3·5 (or 3½) to 73·5 (or 73½), and so on to the end. If the values of the B line be assumed to be one tenth less than the above, then the relative values of the figures with the slide in the same position will be :—

A	21	31·5	42	52·5	63	73·5	84	94·5	105	115·5	126
B	·1	·15	·2	·25	·3	·35	·4	·45	·5	·55	·6

A little practice will enable the learner to bear in mind the value he may place upon any number, and to reckon the same number to the right at ten times that amount.

The Slide Rule, or the logarithmic line of numbers, is not used for addition or subtraction, for as was before shewn, the addition of logarithms is equivalent to the multiplication of the natural numbers which they represent, and the subtraction of the one is equivalent to the division of the other.

MULTIPLICATION.

In using the Slide Rule all problems are resolved by proportion, or what is usually called "the rule of three." In the ordinary method of multiplication it seems that there are only two numbers used to find a third—as for example to multiply 4 by 6, the answer comes as 24. But with the Slide Rule 1 (or unity) is the basis of the calculation, and thus we say as 1 is to 4 so is 6 to the answer. This is a "rule of three" sum, as will be more fully shown under that head.

The rule for multiplication by the Slide Rule is:—To either of the given numbers on A set 1 upon B, and against the other number on B is the product of the two numbers on A.

It will be well always to consider the line A as the original logarithmic line or line of numbers, and the B line as the substitute for the compasses, the answers will then be found upon A.

To take the same example as given on page 7: to multiply 15 by 4. Set one upon B to 15 on A, and against 4 on B is 60, the answer on A.

A	15	60 Answer.
B	1	4

The Rule, as now set, is really a rule of three instrument, on which three terms are given to find a fourth, or a scale of proportionals, on which any figure on A has the same ratio to the figure opposite to it on B as 15 has to 1, or as 60 to 4, as shown below.

A	15	45	60	120	300	&c.
B	1	3	4	8	20	&c.

and so on of every other point in the lines A and B.

Multiply 75 by 36.

A	75	2700—Answer.
B	1	36

Multiply $13\frac{1}{2}$ by $5\frac{3}{4}$.

A	13·5	77·62—Answer.
B	1	5·75

Multiply $7\frac{1}{2}$ by $9\frac{1}{2}$.

A	7·5	71·25 or $71\frac{1}{4}$—Answer.
B	1	9·5

When the product of the two numbers is above 1000, the units cannot be seen, but in those cases the units should be multiplied by the units, in thought, thus:—What is the product of 97 by 19? Set 1 on B to 19 on A, and against 97 on B is 1843 on A. The rule will show something over 1840, and to find the exact number of units, multiply the units of the two figures together—9 times 7 are 63: the required unit in the answer will be then 3, making it 1843.

Note.—When the 1 on B has been set to the one factor on A, if it happen that the other factor on B falls beyond the division, on either A or B, divide it by 10 or 100, &c., till the quotient found on B falls under the same division on the line A, and multiply this said division by the same 10, or 100, &c., for the product required.

So when 250 is to be multiplied by 56. Having set 1 on B to 250 on A, although 56 be found on B, it is beyond the end of A; therefore, dividing it by 10, it is seen that opposite the quotient 5·6 on B is the division 1400 on A; which being multiplied by 10, the number 14000 is obtained as the quotient required.

If 250 were to be multiplied by 1120. Having set 1 on B to 250 on A as before, 1120 is beyond the end of B, but being divided by 100, opposite the quotient 11·2 on B is found 2800 on A, which being multiplied by 100 gives against it on A 280000, the product required.

DIVISION.

As multiplication and division are each a proof of the other, they may both be performed the same way; only observing that in multiplication the multiplier is on another line than the product, but in division, the divisor and the dividend are both found upon the same line.

RULE.—When one number is to be divided by another, whether they be whole numbers, mixed numbers, or decimal fractions, the proportion is, as the divisor upon B is to unity on A, so is the dividend upon B to the quotient on A.

To take the example given on page 7 when worked by the compasses.

To divide 60 by 4.

A	1	15—Answer.
B	4	60

Divide 1728 by 24.

A	1	72—Answer.
B	24	1728

Divide 960 by 15.

A	1	64—Answer.
B	15	960

The slide is then set so that any number on B is divided by 15, and the quotient is seen opposite to it upon A.

Divide $20\frac{1}{4}$ by $4\frac{1}{2}$.

A	1	4·5—Answer.
B	4·5	20·25

Note.—When the dividend falls beyond the end of the line B, let it be divided by 10, 100 or some other power of 10, till it falls within the line, and use the quotient instead of it, multiplying the result by the same power of 10 or 100 as it was divided by. Therefore if 14000 is to be divided by 56; having set 1 on A to 56 B, the dividend cannot be found on B till it is divided by 100, the quotient being 140, opposite to which on B is 2·5 on A, which being multiplied by 100, the quotient 250 on A is obtained.

A	1	2·5 read as 250—Answer.
B	56	140 read as 14000

THE RULE OF THREE.

As before stated, all problems to be worked by means of the Slide Rule resolve themselves into Proportion, or, as it is commonly called, the Rule of Three, from having three terms given by which to find a fourth. *Proportion* differs from *ratio*. *Ratio* is the relation of two quantities of the same kind, as the ratio of 5 to 10, or of 8 to 16. *Proportion* is the likeness, or sameness, of two such relations. Thus, 5 is to 10 as 8 to 16; that is, it bears the same relation to 10 as 8 does to 16. Such numbers are said to be in *proportion*, and are expressed by the signs of proportion by means of dots, thus : :: : which are used as below:

5 : 10 :: 8 : 16

which means that 5 is to 10, or bears the same proportion to it, as 8 does to 16.

The use of the Rule of Three is to find a fourth number which shall have the same ratio, or be proportional, to the third as the second is to the first. Proportion is said to be either "direct" or "inverse," and whether the problem is performed upon the rule or upon paper, it is necessary to be able to distinguish the one from the other. Proportion is direct when all the terms have either an increasing or a decreasing ratio—when "more requires more," or "less requires less." *More* goods at a price require *more* money to purchase them; and *less* quantity of goods requires *less* money. This is direct proportion. But if 3 men can do a piece of work in 12 days, it would take far less time for 4 men to do the same. Here four men (*more*) would require *less* time, which is "inverse" proportion; and in all cases where "more requires less," or "less requires more," the proportion is inverse.

DIRECT PROPORTION,

OR THE RULE OF THREE DIRECT.

The rule for direct proportion is as the first term on B is to the second on A, so is the third term on B to the fourth on A: always remembering that the first and third terms be found on the same line, and the second and fourth upon the other; or the operation may be performed by having the first and third terms on B and the second and fourth upon A.

If 8 yards of cloth cost 24 shillings, what will 96 yards cost? Having set 8 on B to 24 on A, opposite 96 on B stands 288 shillings or £14. 8s., the answer on A.

A	24 shillings.	288 shillings.—Answer.
B	8 yards.	96 yards.

If 6 yards of stuff cost 20 shillings, what will 30 yards cost?

A	20 shillings,	100 shillings.—Answer.
B	6 yards.	30 yards.

If 3 cwt. of iron cost 9 shillings, what will 30 cwt. cost?

A	9 shillings.	90 shillings.—Answer.
B	3 cwt.	30 cwt.

Because there are 20 shillings in a pound, and also 20 cwt. in a ton, the rule when thus set is a table of shillings and hundred weights, also of tons and £'s.; for against any number of tons on B is the value *in £'s* on A at the same price per ton. Or, B is a line of any number of cwts. against the value in shillings on A. Thus:—

A	3	9	18	30	75 shillings	(Or £s.)
B	1	3	6	10	25 cwts.	(Or tons.)

If a person can walk 4½ miles in one hour, how many miles can he walk in 20 at the same rate, not allowing for rest?

A	4·5 (or 4½)	90 miles.—Answer.
B	1	20

If two men 160 miles apart started to meet each other, the one at the rate of 5 miles and the other at 3 miles an hour, how far would each have gone before they met? 5 and 3 miles added together make 8, which, on B, place against 160 on A. Then against 3 and 5 on B respectively is 60 for the one and 100 miles for the other.

A	16 (read as 160)	60 miles and 100 miles.—Answer.	
B	8	3	5

INVERSE PROPORTION.

OR THE RULE OF THREE INVERSE.

In this rule there are three numbers given to find a fourth, that shall have the same proportion to the second as the first has to the third. If *more* requires *less*, or *less* requires *more*, the third term on B is to the second on A as the first on B is to the answer on A.

When the proportion is inverse, the slide is to be inverted or put in the groove the opposite way to what is usual, and then the question will be answered in the same way as when the proportion is direct.

If 6 men can perform a piece of work in 10 days, how many men would be required to do the same in 3 days?

Invert the slide, set 10 upon ꓭ to 6 on A, and against 3 upon ꓭ stands 20 on A, the answer.

A	6	20—Answer.
ꓭ	10	3

Upon some rules the A line is marked upside down, or rather, inverted end for end, to avoid the necessity of turning the slide, but as it is only occasionally so required, it is preferable to invert the slide when requisite.

LEVERS.

There are three kinds of levers wherein the weights, props, or powers, are differently applied to the beam or inflexible bar. The first is when the weight is placed at one end, the power at the other, and the fulcrum somewhere between them; the second is when the power acts at one end, the fulcrum is at the other, and the weight to be raised somewhere between the two; the third is when the fulcrum is at one end, the weight at the other, and the moving power somewhere between.

What weight, hung at 79 inches distance from the fulcrum of a steelyard, will equipoise 900lbs. freely suspended at 2 inches distant on the contrary side?

Invert the slide, and set 2 upon Ɔ to 900 upon A, and against 70 upon Ɔ is 25·71 lbs. or 25¾ lbs. nearly, the answer, upon A.

A	25·71—Answer	900
Ɔ	70	2

What weight will a man be able to lift with a handspike 100 inches long, when he has one prop conveniently fixed at 6 inches from one end, and he presses upon the other end with a force equal to 150 lbs.?

Invert the slide, and set 94 upon Ɔ to 150 upon A, and against 6 upon Ɔ is 2300 lbs., the answer, upon A.

A	150	2300 lbs.—Answer.
Ɔ	94	6

A lever, 16 inches long, having the prop or centre fixed at one end, and a force of 50 lbs. lifting at the other, what weight, hung at 16 inches from the prop, may be raised by the above force?

Set 80 upon Ɔ to 50 upon A, and against 16 upon Ɔ is 250 lbs., the answer, upon A.

A	50	250 lbs.—Answer.
Ɔ	80	16

What weight, hung at the end of a lever at 112 inches from the fulcrum, will balance 1 ton, or 2240 lbs., hung 2 inches from the fulcrum on the opposite side?

112 on B being set to 2240 on A, against 2 on B is 40 lbs., the answer, on A.

The lever of a safety valve being 20 inches long, and 5 inches between the fixed end and the centre of the valve, what pressure on the under side of the valve will raise a weight of 10 lb. placed at the end of the lever?

Set 20 upon Ɔ to 10 on A, and against 5 on Ɔ is 40 lb. on A, the force required.

A	10	40 lbs.—Answer.
Ɔ	20	5

If a steelyard, the lever of which is 40·5 inches in length, the fulcrum 1·5 inch from the end, has a weight of 112 lbs. attached to the short end—required the weight at the other end of the lever to equipoise.

Set 1·5 on D to 112 on A, and against 42 on D (the long end of the lever) is 4·3 lbs., the weight on A.

A	4·3 lbs.—Answer.	112
D	42	1·5

VULGAR AND DECIMAL FRACTIONS.

To reduce a vulgar fraction to its equivalent decimal expression. Rule: As the denominator upon B is to 1 upon A, so is the numerator upon B to the decimal required upon A.

1.—Reduce a $\frac{1}{4}$ to its decimal expression.

Set 1 upon A to 4 upon B then against 1 upon B is ·25, the answer, upon A.

A	1	·25—Answer.
B	4	1

Reduce $\frac{9}{12}$ to a decimal.

A	1	·75—Answer.
B	12	9

Reduce $\frac{13}{27}$ to its equivalent decimal expression.

A	1	·481—Answer.
B	27	13

What is the decimal expression of $\frac{9}{20}$?

A	1	·45—Answer.
B	20	9

What is the decimal expression of $\frac{18}{28}$?

A	1	·643—Answer.
B	28	18

To find a multiplier to a divisor that shall perform the same by multiplication as the divisor would do by divison. The proportion is, as the divisor upon B is to 1 (or unity) upon A, so is unity upon B to the multiplier required upon A.

If 25 be the divisor, what will be the multiplier to that number?

Set 1 upon A to 25 upon B, and against 1 upon B is ·04 the multiplier upon A.

What will be the multiplier to 80?

Set 1 upon A to 80 upon B, and against 1 upon B is ·0125 upon A.

Having a multiplier given to find a divisor.

The proportion is, as the multiplier upon B is to 1 upon A so is the divisor upon A to 1 upon B.

Let ·04 be the multiplier given to find a divisor.

Set 1 upon A to ·04 upon B, and against 1 upon B is ·25 upon A.

What will be the divisor for ·0125?

Set 1 upon A to ·0125 upon B, and against 1 upon B is ·80 upon A.

What will be the divisor for ·7854?

Set 1 upon A to ·7854 upon B, and against 1 upon B is ·1273, the answer, upon A.

The following tables of the decimal expression of fractions of a £, a pound a cwt., and a ton will frequently be found useful in using the Slide Rule.

DECIMALS OF A £.

s.	d.		s.	d.		s.	d.		s.	d.	
0	3	·0125	5	3	·2625	10	3	·5125	15	3	·7625
0	6	·025	5	6	·275	10	6	·525	15	6	·775
0	9	·0375	5	9	·2875	10	9	·5375	15	9	·7875
1	0	·050	6	0	·300	11	0	·550	16	0	·800
1	3	·0625	6	3	·3125	11	3	·5625	16	3	·8125
1	6	·075	6	6	·325	11	6	·575	16	6	·825
1	9	·0875	6	9	·3375	11	9	·5875	16	9	·8375
2	0	·100	7	0	·350	12	0	·600	17	0	·850
2	3	·1125	7	3	·3625	12	3	·6125	17	3	·8625
2	6	·125	7	6	·375	12	6	·625	17	6	·875
2	9	·1375	7	9	·3875	12	9	·6375	17	9	·8875
3	0	·150	8	0	·400	13	0	·650	18	0	·900
3	3	·1625	8	3	·4125	13	3	·6625	18	3	·9125
3	6	·175	8	6	·425	13	6	·675	18	6	·925
3	9	·1875	8	9	·4375	13	9	·6875	18	9	·9375
4	0	·200	9	0	·450	14	0	·700	19	0	·950
4	3	·2125	9	3	·4625	14	3	·7125	19	3	·9625
4	6	·225	9	6	·475	14	6	·725	19	6	·975
4	9	·2375	9	9	·4875	14	9	·7375	19	9	·9875
5	0	·250	10	0	·500	15	0	·750	20	0	1·000

DECIMALS OF A POUND.

Ounces.		Ounces.		Ounces.		Ounces.	
1	·06	5	·31	9	·56	13	·81
2	·12	6	·37	10	·62	14	·87
3	·19	7	·43	11	·69	15	·94
4	·25	8	·50	12	·75	16	1·00

DECIMALS OF A CWT.

lbs.		lbs.		lbs.		lbs.	
7	·0625	35	·3125	63	·5625	91	·8125
14	·125	42	·375	70	·625	98	·875
21	·1875	49	·4375	77	·6875	105	·9375
28(¼ cwt.)	·250	56(½ cwt.)	·500	84(¾ cwt.)	·750	112	1·000

DECIMALS OF A TON.

Cwts.		Cwts.		Cwts.		Cwts.	
1	·05	6	·30	11	·55	16	·80
2	·10	7	·35	12	·60	17	·85
3	·15	8	·40	13	·65	18	·90
4	·20	9	·45	14	·70	19	·95
5	·25	10	·50	15	·75	20	1·00

INVOLUTION

is merely the multiplication of a number by itself—twice for the square, three times for the cube, four times for the fourth power and so on. Thus $3 \times 3 = 9$, 9 being the square of 3. The third yower of 3 is $3 \times 3 \times 3 = 27$ the cube of 3, 64 is the fourth power, &c.

TO FIND THE SQUARE OF ANY NUMBER.

To find the square, or second power of 23.

Set 1 upon B to 23 on A, and against 23 on B is 529 upon A, the answer required.

A	23	529—Answer.
B	1	23

When 16 on C is opposite to 4 on D, the C line is a table of squares and the D line is a table of roots; so that opposite any number on C is its square root on D, thus .

Opposite Square, 16, 25, 36, 49, 64, 81, 100, &c. on C.
are Roots 4, 5, 6, 7, 8, 9, 10, &c. on D.
and in like manner the squares and roots of all other fractional and intermediate numbers may be found.

If the given number be hundreds, reckon the 10 on D for 100 or 1000; then the corresponding 1 on C is 10000 or 100000. So the square of 230 is found to be 529000.

TO FIND THE CUBE OF ANY NUMBER.

Find the number to be cubed on the line C, which place opposite to 10 on D; then opposite the same number on D is its cube on C.

Required the cube of 3. Place 3 on C to 10 on D, and opposite 3 on D is 27 on C.

C	3	27—Answer.
D	10	3

Required the cube of 5.

C	125—Answer.	5
D	5	10

In this last example the radii not extending far enough to the right hand, the answer must be sought in a preceding part of the radius to what it would be were the radii carried out to a greater length.

EVOLUTION

is the extraction of the roots of any number, the square root, the cube root, &c.

THE EXTRACTION OF THE SQUARE ROOT.

The line D being a radius double in length to the line C contains the square roots of all numbers in the line C. The line D though commencing with 4 instead of 1 as does the Routledge rule and others, is nevertheless capable of showing the square roots as those do. By placing the 1 upon C to the 10 upon D the line C is a table of numbers, and the line D a table of their square roots as was before shown on page 21.

C	16	25	64	100	256	400	529	900—Squares.
D	4	5	8	10	16	20	23	30 —Square roots.

THE EXTRACTION OF THE CUBE ROOT.

Reverse the slide in its seat; place the given number on ꓷ to 10 on D; the cube root will be found the divisions of the same numbers coincide.

Thus to find the cube root of 64.

ꓷ	64	4—Answer.
D	10	40

In this case it will be seen that the only two prime numbers of similar values (or tens of such) are the 40 on D and the 4 on C.

MULTIPLICATION BY SQUARED NUMBERS.

This is effected by the lines C and D.

To multiply $7{\cdot}5^2$ by 4. The square of 7·5 is 56·25 and multiplied by 4 gives 225.

Place 4 on C to 10 on D, and over 7·5 on D is 225 on C, the answer.

C	225—Answer	4
D	7·5	10

DIVISION BY SQUARED NUMBERS.

To divide 6^2 by 4. Place 4 on C to 4 on D, and over 6 on D is 9 on C, the answer.

C	4	9—Answer.
D	4	6

To divide 12^2 by 8.

C	8	18—Answer.
D	8	12

TO DIVIDE SQUARED NUMBERS.

To divide 16^2 by 8. Place 8 on C to 8 on D, and over 16 on D is 32 the answer on C.

C	8	32—Answer.
D	8	16

TO FIND A MEAN PROPORTIONAL BETWEEN TWO NUMBERS.

A mean proportional is such a number that if squared it will be equal to the product of the two given terms. To give a very simple example first: Required a mean proportional between 4 and 64. 4 multiplied by 64 = 256, the square root of which is 16, which is the mean proportional between these numbers.

C	4	64
D	4	16—Answer.

Required a mean proportional between 8 and 24.

C	8	24
D	8	13·85—Answer.

Here it will be found that the product of 8 × 24 is 192, and the square of 13·85 is 191·82, which is within a very small fraction of being quite correct.

A mean poportional between 29 and 320 is 96·3; also the mean proportional between 71 and 274 is 139.

TO FIND A THIRD PROPORTIONAL BETWEEN TWO NUMBERS.

Place the first term on B under the second term on A, and over the third term on B is the fourth on A.

The 3rd proportional to 73 and 14 is 2·7 (or more accurately than the rule shows 2·682.)

A	14	2·7—Answer.
B	73	14

The 3rd proportional to 17 and 29 is 49.

A	29	49—Answer.
B	17	29

TO FIND A FOURTH PROPORTIONAL.

This is only another name for the Rule of Three, which has been already explained. We may, however, repeat the rule. Set the first term on B to the second on A; then against the third term on B is the fourth proportional sought on A.

As 12 : 28 : : 114 to the answer sought.

A	28	266—Answer.
B	12	114

MENSURATION OF SUPERFICIES.

AS BOARDS, GLASS, PAINTING, WAINSCOTING, TILING, PAVING, PLASTERING, LAND, &c.

This operation is performed by the lines A and B.

RULE.—If the length is in feet and the width in inches, the divisor or gauge point is 12 on B, to which set the width on A; then against the length on B will be found the number of square feet on A.

When the length and breadth are both in inches, the gauge point is 144; but if all are in feet, then multiply the length by the breadth, and you will have the measure in square feet.

What is the content of a board 15 inches broad and 14 feet long? Set 12 on B to 15 on A, and against 14 on B is 17·5 or 17½ feet the Answer.

A	15	17·5 or 17½ feet.—Answer.
B	12 (G.P.)	14

What are the contents of 13 boards of similar dimensions?

Set 17·5 feet (the contents of one board) on A to 1 upon B, and against 13 upon B is 227·5 feet on A. By a similar operation the contents of any number of boards may be found.

A	17·5	227·5—Answer.
B	1 (G.P.)	13

If a board be 20 feet long and 15 inches broad, how many superficial feet does it contain?

A	20	25 square feet.—Answer.
B	12 (G.P.)	15

How many superficial feet are contained in a door, height 6 feet 6 inches, and breadth 34 inches?

A	6·5	18·4 or 18 feet 5 inches.—Answer.
B	12 (G.P.)	34

What is the content of a window 5¾ feet high, and 46 inches wide? Set 5¾ on A to 12 on B, and opposite 46 inches (the breadth) on B, are 22 feet ½ inch on A, the Answer.

A	5·75	22·1 feet.—Answer.
B	12 (G.P.)	46

In the first, and in the last three examples, the divisor, or gauge point is 12, because the measurements are given in inches.

GLAZIERS' WORK; PAINTING, &c.

Is usually measured by the square yard, containing 9 square feet. The divisor in these cases is therefore 9.

RULE.—Set the length in feet on A to 9 on B, and against the breadth or height in feet on B will be found the answer in yards on A.

Required the content of work 31 feet long and 14 feet wide?

A	31	48 yards 2 feet.—Answer.
B	9 (G.P.)	14

Required the superficial feet in a window 60 inches high, and 50 inches wide? Here the divisor is 144, that being the number of square inches in a square foot.

A	60	20 feet 10 inches.—Answer.
B	144 (G.P.)	50

PAVIOUR'S WORK.

Required the number of square yards contained in a piece of paving 16½ feet long by 13¾ feet wide. Set 9 on B to 16·5 or 16½ on A, and against 13·75 or 13¾ on B is found 25 yards, the content on A.

A	16·5	25 yards.—Answer.
B	9 (G.P.)	13·75

Required the number of bricks sufficient for the above 25 yards of paving (the size of the bricks being 9 inches by 4½ inches) of which bricks 32 make a superficial yard. Set 1 on B to 32 on A, and against 25 on B are 800 bricks, the content, on A.

A	32	800 bricks.—Answer.
B	1 (G.P.)	25

Required the content in roods of a piece of walling 876 feet long and 5 feet high. Set 272¼, which is the area in feet of a rood on B, to 876 the length on A, and against 5 the height on B, are 16 roods nearly on A, the Answer.

A	876	16 roods.—Bare Answer.
B	272·25 (G.P.)	5

TILING AND SLATING

Is measured by squares of 100 feet.

Required the number of SQUARES contained in a piece of tiling 40 feet by 15 wide.

A	40	6 squares or 600 feet.—Answer.
B	100 (G.P.)	15

Required the number of roods in the above dimensions? As a rood contains 63 feet, take 63 for the gauge point, thus:

A	40	9½ roods.—Answer.
B	63 (G.P.)	15

Required the number of tiles to cover the same dimensions. Set 1 on B to 101½, the tiles in a rood on A, and against 9½ on B is 965 the number of tiles required on A.

A	101·5 or 101½	965 tiles.—Answer.
B	1 (G.P.)	9½

LAND MEASURING.

The gauge points or divisors to be used for land measuring are the number of square chains, square perches, and square yards in an acre. If the dimensions are given in chains, the gauge point is 1 or 10; if in perches, it is 160; but if it is given in yards, it is 4840; all upon B.

RULE.—To the gauge point, whether for chains, perches, or yards on B, set the length on A, and against the breadth on B is the content on A.

Required the content of a piece of land, the length of which is 20 chains 50 links, and the width 4 chains 40 links.

A	20·5	9 acres.—Answer.
B	1 (G.P. for chains)	4·4

Required the content of a piece of land, of which the length is 179 perches, and breadth 37 perches.

A	179	41½ acres.—Answer.
B	160 (G.P. for perches)	37

How many acres are contained in a field, the length of which is 35·25 perches, and breadth 22·5 perches.

A	35·25	4·95 acres.—Answer.
B	160 (G.P. for perches)	22·5

Required the content of a field 70 yards long by 70 yards wide.

A	70	1·01 or $1\frac{1}{100}$ acre.—Answer.
B	4840 (G.P. for acres)	70

What is the content, in acres, of a piece of land 440 yards long and 44 yards broad?

A	440	4 acres.—Answer.
B	4840 (G.P. for acres)	44

TIMBER MEASURING.

Boards and Planks are measured as described with examples under "Mensuration of Superficies" on page 24. If the breadth varies, a mean breadth must be obtained by adding the various measurements together, and dividing by their number.—RULE: Set 12 on B to the mean breadth in inches on A, and against the length in feet on B will be found the area in feet on A.

If a board is 15 feet long, 14 inches broad at one end, and 8 inches at the other, required the superficies. The mean breadth being 11 inches (half the sum of 14 and 8).

A	11	13·75 or 13¾ feet.—Answer.
B	12	15

If a board of 18 feet long be irregular in the breadth, say of seven breadths measured at each, take the measure at each of the ends, and at the 3, 6, 9, 12, 15 feet also. Add those together, and divide by 7.

Or, suppose the breadth of one end be 11 inches, and at the other 7 inches; add these together and take the half, which is 9. The breadths at intervals of 3 feet along it are 22, 31, 25, 23, and 13 inches. Add these five breadths together, 114 to 9, (half the sum of the end breadths) which will give the sum of 123 inches. Then setting 12 on B against 123 upon A, against 3 on B will be found 30¾ feet, the answer upon A.

A	123	30·75 (or 30¾) feet.—Answer.
B	12	3

Square or Four-sided Timber, of the same size throughout its entire length, may be converted into cubic measure by means of the gauge points in the table, examples of which are given on pages 29 and 30. Another method is to multiply the breadth by the thickness, and the product by the length, which gives the answer.

To find the Cubic Content of Round Timber.—Rule: As the length is to 12 (or 10) on D so is the quarter girt in 12ths (or 10ths) on D to the content on C.

When the tree tapers, take the mean dimensions either by girting it in the middle, or at the two ends, and taking half the sum of the two. When the tree is very irregular take the mean of several measurements.

This rule, which is commonly used, gives the answer about one fourth less than the true quantity in the tree, or nearly what it would be after being hewn square in the usual way; so that it seems intended to make an allowance for the squaring of the tree. The more correct way is:—as double the length on C is to 12 (or 10) on D, so is 1-5th of the mean girt in 12ths (or 10ths) on D to the content on C.

Another method is to set the length in feet on C to 10·63 on D, and against the quarter girt *in inches* on D will be the content in cubic feet upon C.

The reason 10·63 is taken here for the gauge point is, that 10·63 inches is a quarter of the girt or circumference of a circle, the area of which is 1 square foot.

Required the content of a piece of round timber 32 feet long the quarter girt being 11 inches. Set 32 upon C to 10·63 upon D, and against 11 on D will be found upon C 34·25 or 32¼ cubic feet the contents required.

C	32	34·25 or 34¼ feet.—Answer.
D	10·63	11

Set the length in feet upon C against 10·63 upon D, and against half the sum in inches of the quarter girts at the two ends on D, will be found the contents in cubic feet on C. Then set one-third of the length in feet upon C against 10·63 upon D, and against half the difference in inches of the quarter girts at the two ends on D will be found a second content in cubic feet on C. Add these two contents together, and the sum is the total content required.

With rough, unsquared timber, buyers often get an allowance of one inch in every foot of quarter girt for the bark, and a further allowance for the loss in squaring down the tree to make timber of useful shape. The whole so taken off to make it square will be about 35 per cent., or a third. If the length on C is set to 12 on D instead of 10·63, it will give allowance of about 22 per cent. which is often adopted.

MEASURING AND WEIGHING OF SOLID BODIES.

In measuring solid bodies it is needful to have a table of "gauge points," or "divisors," adapted to the forms of the respective bodies, whether they are right angled, cylindrical or globular. Also when the weights are required, to have a similar table with the gauge points referable to the respective specific gravities of the various bodies in question. Such a table is marked on the Hawthorn Slide Rule, a copy of which we herewith give. It will be seen to be composed of three chief portions to be used in estimating; one for right angled vessels and bodies, one for cylinders, and one for globes. The first column under the head of "SQUARE OR RIGHT ANGLED BODIES" marked FFF contains the gauge points when the dimensions are all in feet. The second column, FII, contains the gauge points, when the dimensions are in feet and inches; and the third III, when they are all expressed in inches. A CYLINDER having but two dimensions, height and diameter, has but two columns of gauge points; that headed FI is used when the length is in feet and the diameter is in inches; and that marked II when both measurements are in inches. A GLOBE having but one dimension has but one gauge point, marked F when it is in feet, and another marked I when the size is given in inches.

Note.—All the gauge points are to be found on the line A.

The lengths, whether square or round, must be found on the line B, and are to be set to the respective gauge points, on the line A.

All squares and diameters must be found on the line D, opposite to which on C will be found the answer.

RULE: As the length upon B is to the gauge point upon A, so is the square or diameter upon D to the content upon C.

A TABLE OF GAUGE POINTS OR DIVISORS,

TO BE USED WITH

HAWTHORN'S LOCOMOTIVE ENGINEERS' SLIDE RULE,

IN MEASURING AND WEIGHING SQUARE OR RIGHT-ANGLED VESSELS OR BODIES, CYLINDERS, AND GLOBES.

	SQUARE OR RIGHT-ANGLED BODIES.			CYLINDERS.		GLOBES.	
	Feet only. FFF	Feet and In. FII	In. only. III	Feet and In. FI	In. only. II	Feet F	In. I
Cubic In...........	36	518	624	660	799	625	119
Cubic Ft...........	625	9	108	114	138	119	206
Imperial Gal.......	10	144	174	184	22	191	329
Water in lbs.......	10	144	174	184	22	191	329
Gold in lbs.	507	735	88	96	118	939	180
Silver in lbs.	938	136	157	173	208	173	354
Wrought Iron ...	129	186	222	235	283	247	423
Cast Iron and Spelter in lbs....	139	2	241	254	304	265	458
Steel in lbs.	136	183	22	233	278	239	418
Copper in lbs.......	112	163	196	207	247	214	371
Brass in lbs.	12	174	207	221	265	23	397
Tin in lbs.	137	135	235	25	300	261	454
Lead in lbs.	880	126	152	162	194	169	289
Mercury in lbs. ..	738	122	127	132	162	141	242
Coal in lbs..........	795	114	138	146	176	151	262
Freestone in lbs.	394	57	69	728	873	755	132
Marble in lbs. ...	370	53	637	725	81	72	121
Dry Oak in lbs....	108	158	190	2	237	208	355
Rd. Deal in lbs....	151	22	263	285	236	287	501
Mahogany in lbs.	94	136	164	175	208	18	336
Boxwood in lbs.	968	152	169	194	214	186	32
Oil in lbs.	108	1565	189	199	238	207	358

In measuring or weighing square timber, stone, metals, or any other bodies which are unequal sided, a mean proportion must be found to ascertain the true square; this is done by the rule "to find a mean proportion between any two numbers," given on page 23.

How many cubic feet may be contained in a cistern 28 feet long, 7 feet wide, and 6 feet deep?

Find a mean proportional between the length and width (28 and 7) as explained on page 23, by setting 28 on C to 28 on D, and against 7 on C is found the mean square, 14 feet on D.—The gauge point for "cubic feet," on reference to the table, will be seen to be 625. Set 6, the depth, on B to 625 (the gauge point) on A, and against 14 on D is 1176 cubic feet, the answer on C.

C	28 (gauge point)	7
D	28	14 feet mean square.

A	625 (gauge point)	
B	6	
C		1176 cubic feet, the Answer.
D		14

Required the content in cubic inches of a piece of timber 2 feet long, 12 inches wide, and 12 inches thick. Look to the table of divisors or gauge points, on page 29, and in the line "cubic inches," second column, is the divisor for feet long, inches wide, and inches thick, viz., 518.

Set 2, the length upon B, to 518 the divisor upon A, and against 12 (the breadth and thickness) upon D is 3456 the content in cubic inches upon C.

A	518 (gauge point)	
B	2	
C		3456 cubic inches.—Answer.
D		12

Required the cubic contents of a piece of timber 3 feet square, and 20 feet long.

The dimensions being all in feet, the gauge point for cubic feet under FFF is 625.

A	625 (gauge point)	
B	20 (the length)	
C		180 feet.—Answer.
D		3

THE SAME EXAMPLE WITH THE DIMENSIONS IN INCHES.

The gauge point under III is 108.

A	108 (gauge point)	
B	240 (inches)	
C		180 feet.—Answer.
D		36 (inches.)

How many cubic inches are contained in a piece of stone 30 inches square and 10 feet long? The gauge point, 9, will be found under FII, in line with "cubic feet."

A	9 (gauge point)	
B	10 (length)	
C		62·5 feet.—Answer.
D		30

If the dimensions of the same piece of stone are taken in inches, the gauge point will be in a line with "Cubic Feet," and under "inches only, III." The problem on the rule will then stand thus :—

A	108 (gauge point)	
B	120 (length)	
C		62·5 feet.—The same answer.
D		30

THE WEIGHING OF ANY BODY OR SUBSTANCE is performed after the same manner as measuring, and is done by means of the table of gauge points, but the answer will be in pounds, instead of cubic inches or feet, gallons, &c.

What weight of water will be contained in a cistern 3 feet deep and 28 inches square?

Set 3 on B to 144 (the gauge point in the table for water in lbs.) on A, and against 28 on D is 1020 lbs., the answer on C.

A	144 (gauge point)	
B	3	
C		1020 lbs.—Answer.
D		28

What is the weight of two logs of dry timber, each 20 feet long and 15½ inches square, one being oak the other red deal.

FOR OAK.—Set 20 on B to 158 (the gauge point in the table) on A, which is in a line with "Dry Oak," and under "Square FFF," and against 15½ on D is 1897 lbs. on C.

A	158 (gauge point)	
B	20	
C		1897 lbs.—Answer.
D		15·5

FOR RED DEAL, the gauge point in the table is 22. Set 20 on B to 22 on A, and against 15½ on D is 1360 lbs., the answer on C.

A	22 (gauge point)	
B	20	
C		1360 lbs.—Answer.
D		15·5

If a column of mercury be 29·5 (29½) inches long, and 1 inch square, what is its weight?

A	127 (gauge point)	
B	29·5 (length)	
C		14·5 (14½ lbs.)—Answer.
D		1 (inch square.)

What is the weight of a column of water 1 inch square and 38 feet long?

A	174 (gauge point)	
B	38 (length)	
C		13·75 (13¾ lbs.)—Answer.
D		1 (inch square.)

What is the weight of a solid yard of coal?

A	795 (gauge point)	
B	3 (feet)	
C		2110 lbs.—Answer.
D		3 (feet)

To find the weight of a Bar of each Brass, Copper, and Lead, 6 feet long and 4 inches square.

For Brass:—The gauge point is under FFI, 174.

A	174 (gauge point for Brass)	
B	6	
C		345 lbs.—Answer.
D		4

For Copper:—

A	163 (gauge point for Copper)	
B	6	
C		368·5 or 368½ lbs.—Answer.
D		4

For Lead:—

A	126 (gauge point for Lead)	
B	6	
C		476 lbs.—Answer.
D		4

OF CYLINDERS, GLOBES, AND CONES.

If a cylinder be 6 inches long and 6 inches diameter, how many cubic inches does it contain? The G. P. for cubic inches is 799.

A		799 (gauge point)
B		6 inches length.
C	169 cubic inches.—Answer.	
D	6 inches diameter.	

How many cubic feet are contained in a cylinder 6 feet 6 inches long and 20 inches diameter?

A	114 (G, P.)	
B	6·5	
C		14·3 cubic feet.—Answer.
D		20

Required to find the number of gallons in a column of water 12 feet high and 14 inches in diameter. The gauge point for cylinders under FI (feet and inches) is 184.

A	184 (gauge point)	
B	12 feet	
C		80 gallons.—Answer.
D		14

What is the weight of a millstone 60 inches diameter and 12 inches thick?

This being a cylinder, with both measurements in inches, the gauge point is 873, according to the table page 29.

A		873 (gauge point)
B		12 (inches length)
C	3080 lbs.—Answer.	
D	60	

What will be the weight of a column of freestone 12 feet high and 12·7 inches diameter?

Set 12 on B to 728 (the gauge point for cylinder FI) on A, and against 12·7 on D is 1660 lbs. on C.

A	728 (gauge point)	
B	12	
C		1660 lbs.—Answer.
D		12·7

What is the weight in lbs. of a column of water 6 feet long and 13 inches diameter?

Set 6 on B to 184 (the gauge point) on A, which is under Cylinder FI, and in line with "water in lbs.," and against 13 on D is 345 lbs. nearly, the answer on C.

A	184 (gauge point)	
B	6	
C		345 lbs. nearly.—Answer.
D		13

What is the weight of a solid cylinder of Cast Iron 24 inches high and 12 inches diameter?

Refer to the table of Gauge Points, and opposite to "cast iron" under the head of Cylinders II is the gauge point 304.

A	304 (gauge point)	
B	24	
C		708 lbs.—Answer.
D		12

In the last example the gauge point for inches is used; if the height be taken in feet, then the gauge point will be 254. The answer is the same.

A	254 (gauge point)	
B	1 foot	
C		708 lbs.—Answer.
D		2 feet.

OF GLOBES.

The cubic contents, or weight of a globe is equal to two-thirds of its circumscribing cylinder The gauge points for globes will be found in the table of gauge points on page 29.

Required the weight of a ball of cast iron 12 inches diameter. The divisor or gauge point in the table is 458.

Set 12, the diameter on B, to 458, the divisor on A, and against 12 on D is 235 lbs., the weight, on C.

A	458 (gauge point) for cast iron under Globe I.	
B	12	
C		236 lbs.—Answer.
D		12

To find the weight in lbs. of a globe 5 inches diameter of each brass, copper, and lead.

For Brass.—Set 5 on B to 397 (the gauge point) on A, and against 5 on D is 19·65 lbs. weight, on C.

A	397 (gauge point)	
B	5	
C		19·65 lbs.—Answer.
D		5

For Copper.—The gauge point is 371.

A		371 (G. P.)
B		5
C		21 lbs.—Answer.
D		5

For Lead :—

A	289 (gauge point)
B	5
C	27 lbs.—Answer.
D	5

OF CONES.

A Cone contains one-third the weight or bulk of a cylinder of the same height and diameter. In measuring or weighing Cones, take one-third of the height and proceed as for cylinders.

What will be the content of a cylinder, globe, and cone, separately; the cylinder 12 inches high and 12 inches diameter; the globe also 12 inches diameter and the cone 12 inches high and 12 inches diameter at its base?

For the Cylinder.—Set 12 upon B to 799 the G. P. upon A, and against 12 upon D are 1356 cubic inches, the answer, upon C.

A	799 (G. P.)
B	12
C	1356 cubic inches.—Answer.
D	12

For the Globe.—The gauge point is 119.

A	119 (G. P.)
B	12
C	904 cubic inches.—Answer.
D	12

For the Cone :—

Take one-third of its height, which is 4 inches, and set 4 on B to 799 (the gauge point of the cylinder in inches) on A, and against 12 the diameter on D, are 452 cubic inches, the answer.

A	799 (G. P.)
B	4 inches.
C	452 cubic inches.—Answer.
D	12

All these examples of estimating the cubic contents of vessels and solid bodies, or their weights, are to be performed by means of the table of gauge points given on page 29. If capacity or cubical measurement is required, the side headings marked "cubic inch," "cubic foot," and "imperial gallon" must be used; if weights are required, the other data in lbs. must be employed.

In some books of instruction for the use of Hawthorn's Engineers' Rule, are examples under separate heads for weighing steel, and cast or malleable, and wrought iron, but as all these may be estimated by the foregoing table of Gauge Points in the same manner as other bodies, it is considered needless to repeat them.

MEASURING AND WEIGHING OF LIQUIDS.

MEMORANDA.

A cubic foot contains 6·25 gallons (6¼ gall.)

A cubic yard contains 168·75 gallons (168¾ gall.)

A cubic foot of distilled water at 60° Fahrenheit, and with the barometer at 30 inches, is equal to 277·274 cubic inches. It may be mentioned that the standard gallon of the United States contains but 231 cubic inches, which is almost the same as the old English wine gallon.

A cubic foot of water weighs 62·5 lbs. or 1000 ounces avoirdupois

The measurement of liquids is to be performed by means of the table of gauge points (see page 29) whether the answer is to be expressed in imperial gallons, cubic feet, or cubic inches.

Required the number of gallons that may be contained in a vat 36 inches deep, and 24 inches square. The gauge point for gallons, the measure being given in inches, is 174.

A	174 (gauge point)	
B	36 inches.	
C		74·5 (74½) gallons.—Answer.
D		24 inches.

The next is the same example but with the measurement expressed in feet.

A	10 (gauge point)	
B	3 feet	
C		74·5 gallons.—Answer as above.
D		2 feet.

Again: the same example, but the measure expressed in feet and inches.

A	144 (gauge point)	
B	3 feet.	
C		74·5 gallons.—Answer, as above.
D		24 inches.

In these examples the length and breadth are the same. Where they are different, a mean proportional must be found (rule, page 23), and the operation proceeded with, using the mean proportional as the one factor is, in the above example.

MEASUREMENT OF CIRCLES.

The following formulary will show properties of the circle which are in most general use, and the mode of finding its equal or inscribed square and inscribed equilateral triangle.

$$\text{The side of an equal square} = \begin{cases} \text{the diameter} \times \cdot 886 \\ \text{or} \\ \text{the circumference} \times \cdot 282 \end{cases}$$

$$\text{The side of an inscribed square} = \begin{cases} \text{the diameter} \times \cdot 707 \\ \text{or} \\ \text{the circumference} \times \cdot 225 \end{cases}$$

The side of an equilateral triangle inscribed in a circle = the diameter ÷ 1·15.

of a circle the diameter of which is 1, the circumference = 3·141
or as 7 is to 21·98 or 22 nearly

Of a circle the circumference of which is 1, the diameter = ·7854

Of a circle the circumference of which is 1, the area = ·0795

Of a circle the area of which is 1, the diameter = 1·27

To find the circumference of a circle, the diameter being given; or, the diameter being given to find the circumference.

Set 7 on B to 22 on A, and against any diameter on B is its circumference on A.

A	22	31·4	62·8	94·2	circumferences in inches or otherwise
B	7	10	20	30	diameters in the same denomination

To find the circumference of a circle 52½ inches diameter.

A	3·141 (or 22) dia.	164	inches.—Answer.
B	1 (or 7) circ.	52·5	

What is the circumference of a circle the diameter of which is 28 inches?

A	3·146 (circumference)	88	inches.—Answer.
B	1 (diameter)	28	

Or the figures being reversed upon the lines A and B, the line A will be line of diameters, and B of their relative circumferences.

The diameter of a circle being given to find the area; or the area being given to find the diameter.

Set ·7854 (the area of a circle whose diameter is 1) upon C to 1 or 10 upon D; the lines C and D will then be a table of areas and diameters of the same denomination, for against any diameter upon D is the area upon C.

C	·7854	1·57	23·5	55	areas.
D	1	2	3	7	diameters.

The circumference being given to find the area; or the area being given to find the circumference.

Set ·0795 (the area of a circle whose circumference is 1) upon C to 1 or 10 upon D, and the lines C and D will then be a table of areas and circumferences of the same denomination, for against any circumference upon D is the area upon C, of the same denomination, whether inches, feet, or otherwise.

C	·0795	·1590	·3180	·7155	1·59	areas.
D	1	2	4	9	20	circumferences.

To find the side of a square equal in area to any given circle.

Set ·886 (the side of a square equal to a circle whose area is 1) upon A to 1 upon B; then against any diameter of a circle upon B is the side of a square that will be equal in area upon A.

To find the side of the greatest square that can be inscribed in any given circle.

Set ·707 (the side of a square equal to a circle whose diameter is 1) upon A to 1 upon B, and against any diameter of a circle upon B is the side of its inscribed square upon A.

To find the side of the greatest equilateral triangle that can be inscribed in any given circle.

Set 1·15 upon B to 1 upon A, and against any diameter of a circle upon B is the length of a side of the triangle upon A.

OCTAGONAL AXLES.

The Gauge Points for octagonal rods are for Wrought Iron 225 and for Cast Iron 242.

What are the weights of octagonal shafts of Wrought or Cast Iron, 8 feet long, and measuring 5 inches across between opposite sides on its end?

WROUGHT IRON (OCTAGONAL).

A	225 (gauge point)
B	8 feet long.
C	555 lbs.—Answer.
D	5

CAST IRON (OCTAGONAL).

A	242 (gauge point)
B	8 feet long.
C	516 lbs.—Answer.
D	5

TABLE OF GAUGE POINTS

TO BE USED WITH THE

HAWTHORN LOCOMOTIVE ENGINEERS' SLIDE RULE,

FOR ROPES, CHAINS AND SMALL ROUND AND SQUARE IRON, &c.

UPON THE HAWTHORN RULE, following the table of gauge points, a copy of which is already given on page 29 will be found another table of gauge points to be used in estimating the Weight of Ropes, and Small Round and Square Iron, and in calculating the Strength of Materials, or the Extreme Strain which Ropes, Chains, Iron Bars will bear and the diameters of Piston Rods.

Circumference in Inches.	Weight in Yards. lbs.	Extreme Strain. lbs.	Work with lbs.	Inclined Planes, lbs.
ROPES.	47	140	320	50
Diameter in $\frac{1}{16}$ ths. **CHAINS.**	52	30	78	13
in $\frac{1}{8}$ ths.	Feet long.			
SQUAREIRON	12	642	265	
in $\frac{1}{8}$ ths.				Piston Rods
ROUND IRON.	152	816	338	32

Upon the A line of the rule are also marked the following Gauge Points—

Piston Rods 32
Ropes 47
Chains 52
Square Iron, in. $\frac{1}{8}$ths 12
Round Iron, in. $\frac{1}{8}$ths 152
Governors 187

ROPES.

What is the weight of a rope 25 yards long and 4 inches circumference?

Set 25 on B to 47 on A, and against 4 on D is 53·16 lbs. on C.

A 47 (gauge point)
B 25
C 53·16 lbs.—Answer.
D 4

CHAINS.

What is the weight of a short-link chain, 30 yards long and 6-16ths of an inch diameter?

The gauge point 52 is in a line with Chains, and under Weight in Yards.

Set 30 on B to 52 on A, and against 6 on D is 129·65 lbs. on C.

A	52 (gauge point)
B	30
C	129·65 lbs.—Answer.
D	6

SMALL SQUARE IRON.

What is the weight of a bar of iron 12 feet long and $\frac{5}{8}$ths of an inch square?

The gauge point in the above table is under FEET in a line with Square Iron.

Set 12 on B to 12, the gauge point, on A, and against 5 on D is 15·625 lbs. the answer, on C.

A	12 (gauge point)
B	12 (feet long)
C	15·625 lbs.—Answer.
D	5 (eighths)

SMALL ROUND IRON.

What is the weight of a bolt 18 feet long and $\frac{5}{8}$ths of an inch diameter?

Set 18 on B to 152, the gauge point, on A, and against 5 on D is 18·47 lbs. on C.

A	152 (gauge point)
B	18 (feet long)
C	18·47 lbs.—Answer.
D	5 (eighths)

STRENGTH OF MATERIALS.

ROPES.

What is the extreme strain or weight a 6 inch rope will bear before breaking?

Also with what weight it will safely work in ordinary cases.

And what weight is usually given to it in practice upon inclined planes?

In calculating the load upon the rope on an inclined plane, if the load is to be raised, *add* the friction and weight of the rope and the carriage to the load, for the real weight upon the rope.

If the load has to descend, *deduct* the friction and the weight of the carriage and the rope from the load, to obtain the real weight upon the rope.

N.B.—The load or weight must always be found on C, and the circumference of the rope on D.

The gauge points will be found in the preceding table.

EXTREME STRAIN	A	140 (gauge point)
	B	1
	C	16060 lbs.—Answer.
	D	6 (inches diameter)
WILL SAFELY WORK WITH	A	320 (gauge point)
	B	1
	C	7000 lbs.—Answer.
	D	6 (inches diameter)
INCLINED PLANES	A	50 (gauge point)
	B	1
	C	4485 lbs.—Answer.
	D	6 (inches diameter)

What is the circumference of a rope that will bear or carry 16060 lbs. before breaking? That will safely work with 7000 lbs.? And that will work on an incline plane, agreeably to the data in general practice, with a weight of 4485 lbs?

These questions are the converse of the three above given, the diameter of the rope being required instead of the load or strain.

FOR THE EXTREME STRAIN.—Set 1 on B to 140 (the gauge point) on A and against 16060 lbs. on C is 6, the circumference of the rope in inches on D, and the other two answers may be found in exactly the same way, by referring to the gauge points.

CHAINS.

Required the extreme weight or strain a chain $\frac{8}{16}$ths of an inch diameter will bear before breaking; also, what weight the same will safely work with; and lastly, what weight or load is usually assigned to it on inclined planes.

Find the respective gauge points in the same line as "Chains" and under "Extreme Strain" is 30; under "Work with" 78; and under "Inclined Planes" 13.

EXTREME STRAIN	A	30 (gauge point)	
	B	1	
	C		13350 lbs.—Answer.
	D		8 (sixteenths)

WORK WITH

A		78 (gauge point)
B		1
C	5130 lbs.—Answer.	
D	8 (sixteenths)	

INCLINED PLANE

A	13 (gauge point)	
B	1	
C		3060 lbs.—Answer.
D		8 (sixteenths)

To find the diameter of the chain when the weight or load is given, proceed exactly as in the last cases; only the weight or strain will be in pounds on C, against which will be the diameter of the chain in sixteenth parts of an inch on D.

In calculating the real load, the friction and weight of carriages must be added or deducted, in the same manner as with ROPES worked on INCLINED PLANES.

IRON.

To find the extreme strain a bar of ordinary iron $\frac{7}{8}$ths of an inch square will bear before breaking; and the load it will safely carry when applied as a suspension bar, screwbolt, &c.

EXTREME STRAIN.—Set 1 on B to 642 on A, (the gauge point, which will be found in a line with square iron, and under "extreme strain,") see page 39, and against 7 (the number of eighths square) on D, is 47500 lbs. on C, the extreme strain.

WORK WITH.—Set 1 on B to 265 on A, (the gauge point under "work with,") see page 39, and against 7 on D is 11530 lbs., the weight which the bar will safely carry when applied as above.

How many pounds will a bar of common iron 8-8ths of an inch diameter bear before breaking? And how much will it work with safely?

Under the respective heads, and in a line with round iron, are the two gauge points.

EXTREME STRAIN.—Set 1 on B to 816 (the gauge point, see page 39) on A, and against 8 on D is 4900 lbs. on C.

SUSPEND OR WORK WITH.—Set 1 on B to 338 (the gauge point, see page 39) on A, and against 8 (the diameter in eighths of an inch) on D is 1180 lbs. on C.

DIAMETERS OF PISTON RODS

are found after the same manner, only observe the gauge point is 32, to which 1 or 10 upon B must be set; and against the extreme weight on the piston on C is the diameter of the rod in eighths of an inch on D.

CAST IRON BEAMS.

To ascertain the strength of beams supported at each end and loaded on the centre, find the gauge point on the line B; for beams 1 inch thick the point is 36.

What is the weight in lbs. a beam 3 feet long 3 inches deep and 1 inch thick will bear on its centre before breaking?

Set 3 on A to 36 (the gauge point) on B, and against 3 on D is 6733 lbs. on C.

A 3
B 36 (gauge point)
C 6733 lbs.—Answer.
D 3

To find the load a cast iron beam 6 feet long, 3 inches deep, and 1 inch thick will carry on its centre before breaking.

Set 6 on A to 36 on B, and against 3 on D is 3373 lbs. on C.

What weight will a beam bear, 8 feet long, 2 inches deep, and 1 inch thick, when loaded as above?

Set 8 on A to 36 on B, and against 2 on D is 1124 lbs. on C.

The foregoing examples on the strength of beams show the weight they will bear before breaking; but in practical application the strength should be from 3 to 10 times this reckoning; depending on the nature and purpose for which the beam is to be used. For joists, three times will be generally sufficient; but for machinery, as engine beams, ten times the data, in many cases, is no more than can be safely relied upon. These observations refer to cast iron only; wrought iron beams will bear about one ninth more; but the allowance for practical purposes need not be more than one-half of cast iron.

WROUGHT IRON BEAMS

supported in the centre, and the weight applied at each end. For these the gauge points will be found on B; 204 is the gauge point for beams 1 inch thick.

What is the extreme weight an engine-beam will bear at each end, 15 feet long, 9 inches deep, and 1 inch thick?

Set 15 on A to 204 on B, and against 9 on D is 6870 lbs. on C.

For all practical purposes, cast iron beams should be about double the size of iron. Observe, in both instances, the examples and gauge points are given for beams 1 inch thick, the strength always being in exact proportion with the thickness; so that, twice the thickness will carry twice the weight, and one half the thickness half the weight.

WEIGHTS OF CAST IRON PIPES.

RULE.—As the thickness of the pipe on B is to 102 (the gauge point for pipes 12 inches long) on A, so is the mean diameter on A to the weight in pounds on B.

What is the weight of a cast iron pipe 12 inches long, 8 inches bore, and half an inch thick?

Set 5 on B to 102 (the gauge point) on A, and against $8\frac{1}{2}$ (the mean diameter) on A is 416 lbs. on B.

Required the weight of a pipe 12 inches long, 12 inches diameter in the bore, and 1 inch thick.

Set 1 on B to 102 on A, and against 13 (the mean diameter) on A is $127\frac{1}{2}$ lbs. on B.

What is the weight in cwts. of a pipe 5 feet long, 12 inches diameter inside, and half an inch thick?

In this case the gauge point is 191 on A, which is the thickness it must be set to.

Set 5 on B to 191 on A, and against $12\frac{1}{2}$ (the mean diameter) on A is 327·5 or $327\frac{1}{2}$ lbs. on B.

What is the weight of a pipe 6 feet long, 12 inches bore, and 1 inch thick?

Set 1 on B to 191 on A, and against 13 on A is 681 lbs. on B.

ACCELERATED MOTION.

FALLING BODIES.

Heavy bodies falling near the surface of the earth acquire a speed of $16\frac{1}{12}$ feet the first second, 64·3 feet in two seconds, and 257 in four seconds; therefore if 257 on C be set to 4 on D, the line D is the number of seconds, and the line C is the number of feet fallen.

If a stone falling into a pit should find the bottom at the end of the sixth second, what is the depth of the pit?

Set 257 on C to 4 on D, and against 6 on D is 576 feet on C.

C	257	576 feet.—Answer.
D	4	6

HORSE POWER OF STEAM ENGINES.

RULE.—As the pressure of the steam per square inch on the safety valve on B, is to the gauge point 250 on A, so is the diameter of the cylinder on D, to the horse power on C.

A cylinder being 32 inches diameter, with steam 25 lb. per square inch on the safety valve, required the horse power?

Set 25, the steam pressure, on B, to 250 on A, and against 32 (the diameter of the cylinder) on D, is 64 horse power on C.

A	250 (gauge point)	
B	25 (pressure)	
C	*	64 horse power.—Answer.
D		32 (diam. of cylr.)

What is the horse power when the cylinder is 20 inches diameter, and steam 30 lb. on the safety valve?

Set 30 on B to 250 on A, and against 20 (the diameter of the cylinder) on D, is 30 horse power on C.

A	250 (gauge point)	
B	30 (pressure)	
C		30 horse power.—Answer.
D		20

ANOTHER METHOD by the lines A and B only.

RULE.—As the gauge point, 28, on B is to any diameter on A, so is the same diameter on B to the horse power on A.

A	40 (diameter of cylinder)	57 horse power.—Answer.
B	28 (gauge point)	40

Of a cylinder 60 inches diameter.

A	60 (diameter of cylinder)	129 horse power.—Answer.
B	28 (gauge point)	60

and in like manner for any other cylinder.

GOVERNORS.

To find the number of revolutions a governor will make in a minute, the length of the pendulum or arms to which the balls are attached being given in inches.

RULE.—Invert the slide. Then as 1 on C is to 187 (the gauge point) on A, is the square root of the pendulums or arms in inches upon C to the number of revolutions per minute upon A.

What number of revolutions will a governor make, the pendulums or arms of which are 30¼ inches long?

Invert the slide. Then set 1 on C to 187 on A, and against 5½ (the square root of the pendulums or arm) on C, is 34 on A.

A	34 —Answer.	187
Ɔ	5½	1

COMPARISON OF FRENCH AND ENGLISH MEASURES.

The French Metre is equal to 39·37 English inches. For easy remembrance, it may be noted that it is frequently spoken of as "three threes," 3 *feet* 3 *inches and* ⅜ *ths*. English. It is divided into 10 decimetres, 100 centimetres, or 1,000 millimetres. The following are approximate equivalents of French and English measures, on the lines A and B, and when the lines are set for any pair, they will be comparative scales of those measures throughout their entire length.

If 35 (millimetres) on A be set to 22 (sixteenths of an inch) on B, the line A is a line of millimetres and B is a line of English inches in sixteenths.

If 127 (millimetres) on A be set to 5 (inches) on B, the line A, is a line of millimetres, and B a line of English inches.

If 70 (centimetres) on A be set to 30 (inches) on B, A will be a line of centimetres, and B of English inches.

If 7 (metres) on A be set to 23 (feet) on B, A will be a line of metres, and B one of English feet.

This little book of instruction is not, of course, put forth as a complete exponent of all the wonderful properties of the slide rule. The rule is, however, as perfect in its theoretical accuracy as is the science of arithmetic ; but owing to its limited length in comparison with the illimitable range over which numbers may be extended, the use of the rule must be comparatively limited. The pamphlet is merely intended to draw the attention of the intelligent mechanic to the truthfulness and utility of the Slide Rule, and to induce him to have recourse to those much more elaborate and exhaustive treatises which have been written upon the subject. It is well known that for a century or more the Excise have performed all their calculations by its means, and important testimony to its value was contained in a recent number of *The Ironmonger* in a biographical sketch of Mr. Richard Chamberlain, Chairman of the Finance Committee of the Town Council of Birmingham, and brother of the Right Hon. Joseph Chamberlain, M.P. After referring to the singular success which had attended him in his private undertakings and in his public career, it said, "This fondness for figures, which has proved of such value to him in his character of financial minister of the Birmingham Corporation, is incidentally and curiously manifested in Mr. Chamberlain's attachment to the slide-rule, of which instrument he is a perfect master and an enthusiastic admirer. Indeed, Mr. Chamberlain does not hesitate to attribute a great part of his success in life to his free use of that modern conjuring rod."

ERRATA.

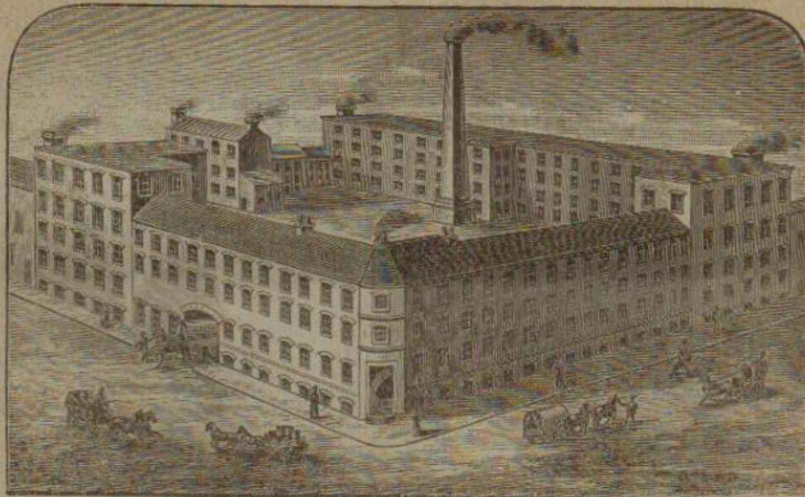
Page 32, line 3, for 174 read 144.

" " " 5, " 13·75 ($13\frac{3}{4}$) read 16·5 ($16\frac{1}{2}$).

Page 37, line 16 from bottom, for dia. read circ.

" " " 15 " " " circ. read dia.

" " " 12 " " " for 3·146 read 3·141.



HOCKLEY ABBEY WORKS, BIRMINGHAM.—JOHN RABONE & SONS.