PURDY

WORK MANUALS. No. II.

THE MECHANICS'

# SLIDE RULE,

## AND HOW TO USE IT.

Being a Compilation of Explanations, Rules and Instructions Suitable for Mechanics and Others Interested in the Industrial Arts.

**Rules are given for the Measurement of all kinds of Boards and Planks, Timber in the Round or Square, Glaziers' Work and Painting, Brickwork, Paviors' Work, Tiling and Slating, the Measurement of Vessels of Various Shapes, the Wedge, Inclined Planes, Wheels and Axles, Levers, the Weighing and Measurement of Metals and all Solid Bodies, Cylinders, Cones, Globes, Octagon Rules and Formulæ, the Measurement of Circles, and a Comparison of French and English Measures, with much other Information, useful to Builders, Carpenters, Bricklayers, Glaziers, Paviors, Slaters, Machinists, and other Mechanics.**

COMPILED AND ARRANGED BY

FRED. T. HODGSON.

PURDY

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# PREFACE.

In an experience of over thirty years in the mechanical arts and sciences, in this and other countries, I have invariably found that the native-born American equals, and in many cases excels, in dextrous manipulation and mechanical skill, his European fellow workman. But while this is true in its general application, I am bound to confess that, although the native is a readier mechanic, prompt, full of expedients, and equal to any passing emergency, his labors and conclusions seem to be more the result of intuition and quick perceptions, than of trained skill or disciplined effort.

Believing these impressions to be based on facts, I am prompted to imagine that Young America has not had the chance his clear mechanical instincts entitle him to, hence the publication of this little manual on the Slide Rule, which I hope may aid him somewhat in acquiring a thorough knowledge of an instrument whose usefulness seems to be but little known on this Continent. Heretofore, all works written on this subject have been above or below general comprehension, but it is believed that the present compilation of instructions and rules will be found to be within the capacity of ordinary intelligence, while the advanced scholar and trained mechanic may find it not devoid of interest and usefulness. To be popular, a work of this kind must be clear and plain, and unless simplicity of language and arrangement characterizes its pages, the mechanical world will scarcely take kindly to it.

Everything of an abstruse nature has been avoided, and as few algebraic formulæ as possible have been introduced in these pages, and it is hoped that plainness and efficiency will be found in every paragraph.

Let Young America take hold of this matter, and it will not be long—with his keen perception and shrewd inventive faculties—before he will extend its usefulness into now unexplored territory.

F. T. H.

New York, 1881.

# THE

# MECHANICS' SLIDE RULE.

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The Slide Rule is formed of two pieces, which are jointed together at one end. When opened it should measure exactly two feet in length. On one side it is figured like any ordinary carpenter's rule; on the reverse side it carries a brass slide in one arm, and is figured to suit the purpose for which it was designed.

The sole reason why the slide rule is capable of performing so many and various operations, rests upon the simple fact that the lines, A, B, C, D, running parallel with the slide, and called the lines of numbers, are divided logarithmetically; therefore it would assist the student materially if he was first instructed as to the nature of logarithms, and the method of their construction and uses.

For our present purposes, however, we need only deal with what are called common logarithms; namely, those which have the same base as our system of numeration, the number 10.

We are aware that 10 by 10, or, as it is called, the square or second power of ten, is equal to 100, and we at once obtain a correct idea of what a logarithm is by putting this simple fact in the form of $10^2 = 100$, where the index of the power (2) to which the base of the system (10) is to be raised is the logarithm of 100.

If we advance a step further, and multiply $100 \times 10$, we get the cube, or third power of 10, that is, $1000 = 10^3$; and, therefore, the logarithm of 1000 is 3, and so on for any power of 10 to which we may wish to go. A series thus arranged would be represented thus:

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| 10, | 100, | 1000, | 10000, | 100000, |

etc., from which it will be seen that the lower line of figures forms a geometrical progression; the upper, a line of inches, or logarithms, forms an arithmetical progression, the former produced by the continual multiplication of the base by the common ratio (10). Hence, in the common system of logarithms the logarithm of any integral power of 10 can be readily determined by the number of ciphers contained in the given number, since the first power 10 has one, the second two, the third three ciphers, and so on for any number.

Of course there are eight integers between 1 and 10, besides all the fractional parts into which these again may be subdivided; and, to avail ourselves of the full value of logarithms as an assistance in intricate calculations, means had to be devised by which the logarithm of any number could be found, whether such number were integral or fractional. Several approximate methods have been found by different mathematicians, and the results of their labors have been tabulated so as to become of the highest utility in some of the most abstruse problems of physical science; but in our present inquiry we shall, in all probability, only require logarithms correct to three decimal places; hence, I consider the following memoranda sufficient for giving a fair insight into the use and capabilities of the slide rule.

1. All numbers and divisions on the rule are to be read decimally, for all the spaces are, or are supposed to be, divided and subdivided into tens and tenths; the visible marks may describe fifths, or halves—these are still equal parts of ten. Where the spaces do not admit of subdivision, the proportions of $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, must be estimated, and when the eye grows accustomed to the scale, with a little practice, tenths of a division may be judged with great accuracy.

2. The figures on the rule are engraved simply as 1, 2, 3, etc., but these numbers are arbitrary, and any required value may be assigned; thus, the 2 may be called 2, or 20, or 200, if it is borne in mind that the figures on the whole line are affected in the same ratio during that operation.

*Ex:* A 2 being called 20, the 3 is 30, and so on throughout the scale on that line; but *different lines* may bear different values if the proportions are maintained. A simple case will illustrate this point.

*Ex:* If 2 feet of walnut cost 20 cents, what will $6\frac{1}{2}$ feet cost, and also 65 feet cost? The reading in the rule would be,

A set 2 feet, 6, 5, and 65 feet.

B 20 cents cost 65 cts., cost 665 cts.

Here we have given the 2 on the *slide* a tenfold value, viz.: 20 cents which extends to the 65 and the 650.

3. The slide rule consists of four lines marked as follows:



A }
B } Being on the slide, the edge B working with A.
C } " " " " " " C " " D.
D }

This arrangement, though compact enough, is puzzling to the beginner, giving an unnecessary appearance of intricacy to a very simple instrument. The following method of reading is considered more simple, and is adopted by many: $\frac{A}{B}$ and $\frac{C}{D}$ are separated, each pair having its own office, instead of a combined and complex operation. What follows on the uses and relation of these lines and slides is greatly assisted by an inspection of a rule at this time.

$\frac{A}{B}$ lines will be found exactly alike in numbers and divisions, and are, therefore, in direct simple proportion, and all questions may be solved by them.

In the foregoing it has been shown that, if we add together the logarithms of two numbers, the sum gives the logarithm of the product of these numbers; and on this principle is founded the method of multiplication by the slide rule.

When the logarithmic line was first placed on scales by Mr. Gunther, it consisted of a single line, such as A on the present rule, and the operations were performed by taking the distances with compasses, and adding and subtracting, according as multiplication or division had to be performed. Thus to multiply $8 \times 4$, we should extend the compasses from 1 to 4, and then, placing one leg upon 8, the other would extend forward to 32. In like manner, if 96 was to be divided by 12, we take in the space from 1 to 12, and measuring back (subtracting), the number indicated would be 8.

I would advise the student to practice this method with his compasses for a while; it will aid him very much in mastering the working of the rule.

This method was very inconvenient, as it necessitated the use of two instruments. It was early superseded by the genius of a clever mathematician named Everard, who gave us the slide and groove as we now have it.

This change rendered a modification of the method of working necessary; hence the general rule is now thus given: Set the 1 on B to the multiplier on A, and against the multiplicand on B is the product on A.

Taking the above example, we place 4 on A against 1 on B, and opposite 8 on B we find 32 on A.

So again, in division, if 96 be divided by 12, we set 12 on A to 1 on B ; and against 96 on A we find 8 on B, being simply the reverse operation to that of multiplication, we subtract the logarithmic distance instead of adding it ; and since these two rules form the basis of all calculations, however complicated they may appear, if they are once thoroughly mastered very little difficulty will be found in making the most intricate calculations.

In the first example shown, it was required to multiply 8 × 4; to do this on the rule the student was told to set 1 on the left-hand corner of the slide on the line marked B, to the multiplier (4) on the line marked A. This being done, run the eye along the brass slide on the line B, until the multiplicand (8) is reached ; then right over that figure, on the line A, will be found the figure 3 and two-tenths of the division between that figure, and the figure 4. Now, in this case, the figure 3 on the A line stands for 30, and the two tenths for 2, which being added together, makes a total sum of 32, which is the product of 8 multiplied by 4. This, I think, is put so plain that any one can understand it.

Where there are two figures in both multiplier and multiplicand—as, for instance, 25 × 35—we must proceed as follows, bearing in mind what has already been said. Now, to multiply 25 × 35, we should take the 1 on the B line on the slide and move it past the figure 2 to the long line between the figures 2 and 3. This long line is five-tenths of the distance between 2 and 3 on the A line, and stands for 25, while in reality it is only 2·5, but by removing the decimal point we make it 25. Now we find the figure 3 on the B line on the brass slide, and call it 30 when found, we add five of the long divisions, or half of the distance between the figures 3 and 4 on the B line ; these five-tenths make the 5, which, with the 3 or 30, make the 35. Now, directly over this long division, last found, will be the figure 8 and the 7½ divisions on the line A, which expressed in numbers is 8·75, and to assign the true value to this result we must remember that, in both multiplier and multiplicand, we divided by ten—that is, we assumed that the small divisions between the larger ones were one-tenth of the latter ; hence, in the product we must account for that suppression by again multiplying by the second power of 10—viz., 100, making the product, instead of 8·75, equal to 875, or removing the decimal point two places to the right.

This operation is one of the most difficult in the way of a beginner, and we cannot too strongly impress upon such the paramount importance of earnestly and thoughtfully studying this portion of the subject, so as to feel conscious that he has completely mastered it before he ventures a single step further.



True, this course will require patience, perseverance, and apparent self denial, but what worth having has ever yet been attained by a mind in which these virtues do not shine pre-eminently ? And when they do once take firm directive power over the mind, it is astonishing how rapidly every difficulty melts down to simplicity.

We are now in a position to consider more fully the difficulty generally experienced in reading off the numbers obtained by the different processes. It must be borne in mind, when dealing with the numbers marked on the rule, that, although they are arbitrary, and hence, for the time being, we can (with the restrictions before noted) call them what we like, yet we cannot really alter their true values, but must always account for the assumed values in the results we obtain ; thus, if we call 2 twenty, and multiply by it, our result will be ten times too much ; and therefore, in valuing such a product, we must always omit the terminal cipher. On the contrary, if we have to multiply by 20, yet only really take twice the quantity, our result is evidently ten times too small ; and hence we must not omit to add a cipher to our result, or, which is the same thing, remove the decimal point one place to the right.

Having arrived at this stage, we will now endeavor to show graphically how the various methods of solving difficult problems are performed:

| A | A |
|---|---|
| B | B |

The line dividing the letters, A A, and B B, is supposed to show the division between the upper edge of the slide, B, and the lower edge of the slide, A. Now let us see how we can make use of this line in working out all subsequent questions:

*Ex.*—If one side of a roof is 12 feet wide and 35 feet long, how many feet of boards will it require to cover it ? Here we have the two figures 12 and 35 to deal with, and, according to the preceding rule for multiplication, we should place the figure 1 on the slide directly under the figure 12, on A, then over 35 on the slide will be found 420, the correct answer. By using the line it will appear thus:

| A | 12 | 420 | A |
|---|---|---|---|
| B | 1 | 35 | B |

when the slide is set as above. If we examine the rule as now arranged, it will be noticed that the 12 and 1 are as written above, but we find the 3 alone, and must therefore call it 30, and add five of the smaller divisions to it and call it 35 ; then, directly over the fifth division on the line A, we find a division two removes from the figure 4, which, added to this last figure, make up the answer sought; *i.e.*, 420. This, we think, is quite plain, and, if what we have already said be borne in mind by the student, the correct readings of what follows will not be a difficult matter.

## MULTIPLICATION.

*Rule.*—To either of the given numbers on A set 1 upon B; then against the other number on B is the product on A.

To take the following example given, which is 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 |

This 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 | etc. |
| B | 1 | 3 | 4 | 8 | 20 | etc. |

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 13½ by 5¾.

| | | |
|---|---|---|
| A | 13·5 | 77·62 Answer. |
| B | 1 | 5·75 |

Multiply 7½ by 9½.

| | | |
|---|---|---|
| A | 7·5 | 71·25 or 71¼ 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, etc., 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, etc., 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.

*Rule.*—As any number on B is to unity on A, so is any other number on B to that standing opposite to it on A.

Divide 84 by 7. Set 7 on B to 1 on A, and against 84 on B is 12 on A.

| | | |
|---|---|---|
| A | 1 | 12 Answer. |
| B | 7 | 84 |

Divide 1728 by 24.

| | | |
|---|---|---|
| A | 1 | 72 Answer. |
| B | 24 | 1728 |

Divide 20¼ by 4½.

| | | |
|---|---|---|
| A | 1 | 4·5 Answer. |
| B | 4·5 | 20·25 |

To divide 300 by 25. Having set 1 on A to 25 on B, opposite 300 on B is found 12 on A, the quotient required.

| | | |
|---|---|---|
| A | 1 | 12 Answer. |
| B | 25 | 300 |

*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.

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 only 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

Mean 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 4 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.



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 velvet cost 24 dollars, what will 96 yards cost ? Having set 8 on B to 24 on A, opposite 96 on B stands 288 dollars, the answer on A.

| | | |
|---|---|---|
| A | 24 dollars. | 288 dollars Answer. |
| B | 8 yards. | 96 yards. |

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

| | | |
|---|---|---|
| A | $20.00 | $100.00 Answer. |
| B | 6 yards | 30 yards. |

If 3 sacks of flour cost $9.00, what will 30 sacks cost ?

| | | |
|---|---|---|
| A | $9.00 | $90.00 Answer. |
| B | 3 sacks. | 30 sacks. |

If a person can walk $4\frac{1}{2}$ miles in one hour, how many miles can he walk in 20 at the same rate, and not allowing for rest ?

| | | |
|---|---|---|
| A | 4·5 (or $4\frac{1}{2}$) | 90 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 | 100 Answer. |
| B | 8 | 3 | 5 |

## RULE OF THREE INVERSE.

When the proportion is inverse, the slide is to be inverted, and then the question will be answered in the same way as in the Rule of Three 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 C to 6 on A, and against 3 upon C stands 20 on A, the answer.

| | | |
|---|---|---|
| A | 6 | 20 Answer. |
| Ɔ | 01 | Ɛ |

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.

## TO SQUARE ANY NUMBER.

Required the square of 23. Set 1 on B to 23 on A, and against 23 on B stands 529 on A.

| | | |
|---|---|---|
| A | 23 | 529 Answer. |
| B | 1 | 23 |

Or by the lines C and D, the same operation may be performed by setting 1 or 100 on C to the 10 on D. When they are thus set, C is a table of squares and D a table of roots; consequently, opposite to any number upon C is its square root upon D, as under:

Squares, 1, 4, 9, 16, 25, 36, 49, 64, 81, upon C.
Roots, 1, 2, 3, 4. 5, 6, 7, 8, 9, upon D.

and the same rule holds good of the fractional or intermediate numbers.

If the given number be hundreds, etc., reckon the 1 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 EXTRACT THE SQUARE ROOT.

*Rule.*—Set 1 or 100, etc., on C to 1 or 10, etc., on D; then against every number found on C stands its root on D. The lines C and D are thus a table of square roots and squares; the roots on D and the squares on C. So against 529 stands its root 23; against 400 stands its root 20; against 300 stands its root 17·3, and so on of all other numbers.



## TO FIND A MEAN PROPORTIONAL BETWEEN TWO NUMBERS.

Suppose between 29 and 430. Set 29 on C to the same number on D; then against the other number 430 on C stands their mean proportional, 111 on D.

Also the mean between 29 and 320 is 96·3.
And the mean between 71 and 274 is 139, etc.

## TO FIND A THIRD PROPORTIONAL TO TWO NUMBERS.

To find one to 21 and 32. Set the first 21 on B to the second 32 on A; then against the second 32 on B stands 48·8 on A, which is the third proportional sought.

Also the 3rd proportional to 17 and 29 is 49·4.
And the 3rd proportional to 73 and 14 is 2·7, etc.

## TO FIND A FOURTH PROPORTIONAL TO THREE NUMBERS.

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.

| | | |
|---|---|---|
| A | 28 | 266 Answer. |
| B | 12 | 114 |

## MENSURATION OF SUPERFICIES.

*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 | 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 the same operation the contents of any number of boards may be found.

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 | 15 |

How many superficial feet are contained in a door, height 6 feet 6 inches, and breadth 34 inches? Set 6½ on A to 12 on B, and opposite 34, the breadth on B, are 18 feet 5 inches on A, the Answer.

| | |
|---|---|
| A 6·5 | 18·4 or 18 feet 5 inches Answer. |
| B 12 | 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.

*Glaziers' Work: Painting, Etc.*, is usually measured by the square yard, containing 9 square feet.

*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 | 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 | 50 |

*Pavior'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.

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.



*Shingling, Flooring, Tiling, and Slating.*—This work 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 | 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 | 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 | 9½ |

*Brick Work.*—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.

## TIMBER MEASURING.

*Boards and Planks* are measured as described, with examples, under "Mensuration of Superficies" on page 15. 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.

*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 other pages. 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 msasurements.

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 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 34¼ cubic feet, the contents required.

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

*To find the Content of a Round Piece of Timber which Tapers from end to end.*—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 content required.

With rough, unsquared timber, buyers often get an allowance of an 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.

A TABLE OF GAUGE POINTS, TO BE USED WITH THE MECHANICS' SLIDING RULE, IN MEASURING AND WEIGHING SQUARE OR RIGHT-ANGLED VESSELS OR BODIES, CYLINDERS AND GLOBES.

| | *Square or Right-Angled.* | | | *Cylinder.* | | *Globe.* | |
|---|---|---|---|---|---|---|---|
| | 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 | 113 |
| 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 |
| Pine 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 |

The foregoing is a table of "gauge points" or "divisors," to be used in estimating the weight or capacity of right-angled, cylindrical, or globular bodies or vessels. Bodies or vessels of which the four corners are right angles have three dimensions, length, breadth, and thickness. The first column marked FFF contains the gauge point, 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.

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 15.

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 20, 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.

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 19, 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.

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 or 62 feet 6 inches | Answer. |
| D | 30 | |

If the dimensions of the same piece of stone are taken in



inches, the gauge point will be under "inches only, III," and the problem on the rule will stand thus:—

| | | |
|---|---|---|
| A | 108 (gauge point) | |
| B | 120 (length) | |
| C | 62·5 or 62 feet 6 inches | 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, only the answer will be in pounds, instead of cubic inches or feet, gallons, etc.

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

Set 3 on A to 144 (the gauge point for gallons in feet and inches) on B, and against 28 on D is 1020 lbs., the Answer on C.

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

*For Oak.*—Set 20 on B to 158 (the gauge point) on A, which is in a line with "dry oak," and under "square FFF," and against 15½ on D is 1897 lbs. on C.

*For Pine.*—The gauge point is 22. Set 20 on B to 22 on A, and against 15½ on D is 1360 lbs., the Answer on C.

*Copper, Brass, Lead.*—To find the weight of bars of brass, copper, and lead, each being 6 feet long and 4 inches square.

*For Brass.*—The gauge point is under "square FII." Set 6 on B to 174 on A, and against 4 on D is 345 lbs. on C.

*For Copper.*—The gauge point is 163. Set 6 on B to 163 on A, and against 4 on D is 368½ lbs. on C.

*For Lead.*—The gauge point is 126. Set 6 on B to 126 on A, and against 4 on D is 476 on C, the Answer.

*Of a Cylinder.*—What is the weight of a cylinder of cast iron 24 inches high and 12 inches diameter? Set 24, the length, on B to 304 (see table of gauge points) on A, and against 12, the diameter, on D is 708 lbs., the content, on C.

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. In either case the answer works out the same.

Required the cubic inches of a cylinder 6 inches long and 6 inches diameter. Here the gauge point under "cubic inches" is 799.

| | | |
|---|---|---|
| A | | 799 |
| B | | 6 (length) |
| C | 169 lbs. Answer. | |
| D | 6 (height). | |

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.

To find the weight of a column of coal the same size as above.

Set 12 on B to 146 (the gauge point) on A, and against 12·7 on D is 827 lbs., the Answer on C.

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.

*Of Globes.*—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.

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.

*For Copper.*—Set 5 on B to 371 (the gauge point) on A, and against 5 on D is 21 lbs. on C.

*For Lead.*—Set 5 on B to the gauge point 289 on A, and against 5 on D is the Answer 27 lbs. on C.

*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.

## LIQUID MEASURE.

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 (see table page 19).



| | | |
|---|---|---|
| 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; the gauge point for which see table, page 19.

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

Again: the measure expressed in feet and inches (3 feet, 24 inches). The gauge point in table is 144.

| | | |
|---|---|---|
| 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 15), and the operation proceeded with, using the mean proportional as the one factor is, in the above example.

How many gallons are contained in a vessel 36 inches square? The gauge point for gallons in inches is 174 (see table). Set 36 on B to 174 on A, and against 36 on D is 168 gallons, the Answer upon C.

## LAND MEASURING.

The gauge points or divisors to be used for measuring land 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 upon A; if in perches, it is 160; but if it is given in yards, it is 4840.

*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 | 4·4 |

Required the content of a piece of land, of which the length is 179 poles, and breadth 37 poles?

| | | |
|---|---|---|
| A | 179 | $41\frac{1}{2}$ acres Answer. |
| B | 160 | 37 |

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

| | | |
|---|---|---|
| A | 70 | 1·01 or 1 1-100 acre Answer. |
| B | 4840 | 70 |

## MEASUREMENT OF CIRCLES.

To find the circumference of a circle, the diameter being given; or, the diameter being given, to find the circumference. The circumference of a circle the diameter of which is 1 is 3·141, or the one is to the other nearly as 7 is to 22. Therefore set 7 on B to 22 on A, and against any diameter on B is its circumference on A. This method also shows the diameter when the circumference is given.

The diameter of a circle being given, to find the area; or, the area 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, for or against any diameter upon D is the area in square inches upon C.

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; for against any circumference upon D is the area in square inches upon C.

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 a triangle upon A.

## THE WEDGE.

Required the power of a blow struck on a wedge, the half-thickness is 1 inch, the length of one side is 25 inches, and the resistance equal to 250 lbs.? As 25 on B is to 250 on A, so is 1 on B to 10 lbs., the Answer, on A.

## INCLINED PLANE.

Given an inclined plane, perpendicular height 12 inches, and length of the slant 36 inches, what weight hung on the perpendicular height will balance 75 lbs. hanging on the slant? Set 36 on B to 75 on A, and against 12 on B is 25 lbs. on A, the Answer.

## WHEEL AND AXLE.

What weight hung on a wheel of 20 inches diameter will balance 100 lbs. hung on the axle, which is but 1 inch diameter? Invert the slide, set 1 on C to 100 on A, and against 20 on C is 5 lbs., the required weight on A.

| | | |
|---|---|---|
| A | 5 lbs. Answer. | 100 |
| C | 20 | 1 |

## THE LEVER.

If a lever be weighed with 672 lbs. on the short arm at 1 foot from the fulcrum, what weight will balance it when hung on the long arm at 6 feet from the fulcrum? As 1 is to 672, so is 6 to the number sought. Invert the slide; set 1 on C to 672 on A, and against 6 on C is 112 lbs., the Answer on A.

## COMPARISON OF FRENCH AND ENGLISH MEASURES.

The French metre is equal to 39·37 English inches. It is divided into 10 decimetres, 100 centimetres, and 1,000 millimetres. The following are approximate equivalents of French and English measures, and when the lines A and B are set for any pair, the lines are comparative scales of those measures throughout their whole length.

| | | | | |
|---|---|---|---|---|
| A | 35 millimetres. | 127 millimetres. | 76 centimetres. | 7 metres. |
| B | 22 sixteenths of an inch. | 5 inches. | 30 inches. | 23 feet. |

Or

| | | |
|---|---|---|
| A | 7 metres. | 49 metres. |
| B | 23 feet. | 121 feet. |

## OCTAGON LINES.

On the opposite, or under side of all American made slide rules, there are two scales near the inner edges, marked respectively M and E. The line marked M is divided into 34 parts, measuring from the end of the scale, and each of these parts is again subdivided into 4 equal parts. The line E is divided into 24 parts, with subdivisions of 4 parts each. The line M is used for measuring from a middle line in obtaining the correct points for forming an octagon on any square material. For example: Let us suppose we have a stick of timber 12 inches on a side, and it is desired to make it octagonal, we find the middle of one side, which is 6 inches from the edge, then apply the rule, putting the end on the middle line, and measuring back to 12 on the M line, and we have the *point* which is to form one corner of the octagon. Repeat the process on all the four sides of the stick, and you have the 8 points to form the octagon. The E line is used for the same purpose, *i.e.:* for finding the points in a square to form an octagon. The measurements, however, on the line E are made from the edge of the stick, instead of on the middle line, so, in the example before us, we find that 12 on the E line stands exactly on a line with 3½ inches, so that, according to what we have stated, 3½ inches from the edge is the point sought, and which forms one angle for the octagon. Repeat the process, and again we have the correct points for reducing the 12-inch square timber to an octagon. The subdivisions, being eight for each large division, show that they are to be used when



fractions of an inch have to be dealt with. Thus: a stick of timber 8½ inches square, if measured for the points on the E line, will require 8 of the larger divisions and 2 of the smaller ones, from the edge to the point. This is obvious, and requires no further explanation. The same method applied to the line M gives the same results. The same result may be obtained by the slide. Set 5 on B to 12 on A, and opposite to the length of the side of any square figure on A is the length of a side of the inscribed octagon on B.

| | | | | |
|---|---|---|---|---|
| A | 10 | 12 | 15 | 18 sq. inches (side of the square.) |
| B | 4⅛ full | 5 | 6¼ | 7½ sq. inches (side of the octagon.) |

## THE ENGINEERS' SLIDE RULE.

Although the present work is not designed to illustrate the capabilities of the "Engineers' Slide Rule," yet it is thought it will not be complete without a description of the rule and the method of applying it.

The four lines on this rule are marked A, B, C, D, the same as on the Mechanics' Rule. A, B, and C are alike; they consist of two radii, and are divided and numbered from the left to the right, with the figures 1, 2, 3, 4, 5, 6, 7, 8, 9; 1, 2, 3, 4, 5, 6, 7, 8, 9, 10. The line D is a single radius, double the length of the other, and is numbered from left to right, with 1, 2, 3, 4, 5, 6, 7, 8, 9, 10; the lines B and C slide between the other two; and by this operation all questions, within the capacity of the rule, are answered.

Numeration is the first thing to be learned upon this, as well as upon the Mechanics' Rule, and when this is perfectly understood, everything else is quite easy. In order, then, that this may be rendered as plain as possible, we again repeat what has been said before—namely, that the numbers and divisions upon the rule are all arbitrary, and the value set upon them must be such as the nature of the questions requires, which will be easily discovered as soon as a question is proposed.

The tedious arithmetical process of working *Cube Root* is performed on the "Engineers' Rule" by mere inspection, the same as *squares* and *roots*, were C a triple line to D single; indeed, any roots and powers might be found by increasing the sections of C to the required power. The present double radius gives the second, the fourth, and eighth powers. In the absence, however, of an arrangement which would affect the simple form—squares and roots being sufficient for all general purposes—a little ingenuity must be substituted to find cube roots; we therefore *reverse the slide*, and, setting the number to 1 or 10 on D, have to look for the numbers or divisions exactly coinciding, which is the required cube root, as in this example—

$\sqrt[3]{64}$

| | | | | |
|---|---|---|---|---|
| S. Inv'd. | find coincident | 4 | cube root | set 64. |
| D | Numbers - - | 4 | of 64 1 | to 10. |

In this case it is easy and evident that no other similar numbers meet; but, sometimes, owing to the different scales of C and D, and the one being inverted, a little patience is needed to mark the intersecting numbers, or

Divisions on { C Inv'd. / D }

the only case in slide rule practice demanding it, but still wonderfully simple compared with arithmetic.

To those acquainted with Evolution, the example given will suffice to enable them to obtain the fourth power and root, for C and D forming lines of squares and roots, we can find the square root of the square root; and consequently, the fourth power or root of any number by inspection.

All of the foregoing is but a fraction of what can be performed on this wonderful instrument, but when the rules we have presented are thoroughly mastered and understood, the student will soon discover for himself many applications that are not to be found in text books.

For further information and applications of the Slide Rule, we refer our readers to the following works on the subject, namely:

To the article "Slide Rule," in the *Penny Encyclopædia*. This article is probably the best short treatise—historical and scientific—that has been written on the subject.

"Mathematical Instruments and Their Use," by J. F. Heather. This is an excellent work, but is not confined altogether to the Slide Rule.

"The Slide Rule," by Charles Hoare. This is an exhaustive work on the subject, and is very thorough, but is written in a style a little above the capacity of ordinary mechanics. It is published by Weale, and contains a paper rule and slides.

"The Engineers' Slide Rule," by William Tonkes. This is



a small work, written in a clear and vigorous style; its only objection is its being devoted altogether to the *engineers' slide rule*.

"The Utility of the Slide Rule," by Arnold Gillson. This is a pregnant little work, and covers a great deal of ground, and is especially adapted for mechanical engineers, millwrights, and constructors of cotton factories.

"Treatise on a Box of Instruments," by Thomas Kentish. This is a purely scientific work of a very high order, and aims over the heads of those who possess only a limited education. For advanced scholars, however, it will be found interesting and instructive.

"Lessons in Carpentry by the Slide Rule," by Robert Riddell. This is one of the best works on the subject, and is suited to any capacity. There are other obscure works in the market, but we would not advise the student to purchase any of them.

Besides the foregoing works, there are many excellent papers on the subject scattered through back volumes of the *English Mechanic*. A number of very useful papers on the same subject have appeared in recent numbers of *The Builder and Woodworker*.

We now leave this little work in the hands of our readers, with a hope that its contents will aid somewhat in creating an interest in the study of the Slide Rule and its Application.

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