

**INSTRUCTION MANUAL
FOR
HEMMI 269
SLIDE RULE**

HEMMI

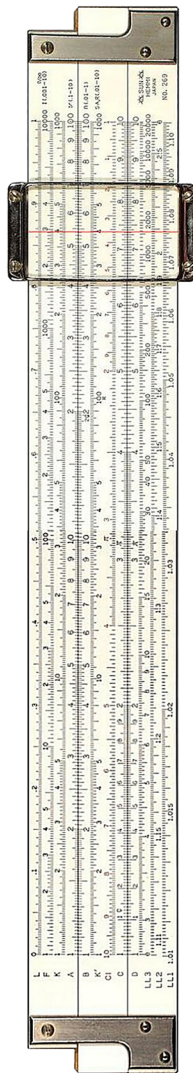
INSTRUCTION MANUAL FOR **HEMMI 269** **SLIDE RULE**

HEMMI SLIDE RULE CO., LTD.

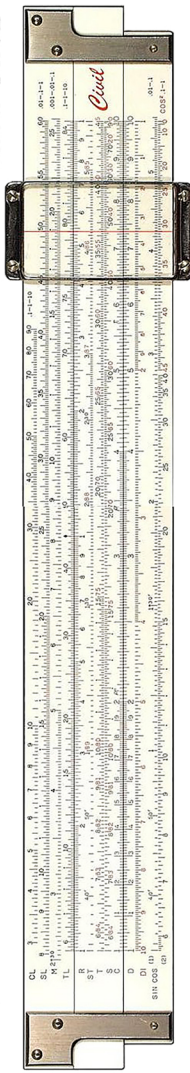
TOKYO, JAPAN

NO. 269 SLIDE RULE

FRONT FACE



BACK FACE



INSTRUCTION MANUAL FOR HEMMI NO. 269 (^{25cm}_{duplex type}) SLIDE RULE

The Hemmi No. 269 slide rule has been specially designed for civil engineers and civil engineering students and incorporates the following features.

(1) CURVE SETTING CALCULATION.

This rule is provided with five special scales for curve setting calculations. CL (curve length), SL (external secant), TL (tangent length) and M (middle ordinate) can be found simply by only moving an indicator when the slide is set in a certain position. This can be effectively used in designing roads and in examining curved tracks.

(2) STADIA CALCULATION.

In a stadia survey, the surveyor reads the angle and the stadia rod readings from the transit. Knowing these readings, the undulation difference and horizontal distance are determined by using the SINCOS and COS^2 scales.

(3) HYDROGRAPHICAL CALCULATION.

The K' scale, which is a three cycle logarithmic scale on the slide, and the F scale, which is a four cycle scale on the body, are jointly used for calculations involving 4th power and $\frac{4}{3}$ power which are often required in hydrography. When used with the A, B, and K scales, these scales simplify the calculations of many problems in hydrography, especially those which utilize Manning's Hydrometric Law.

CHAPTER 1. READING THE SCALES.

In order to master the slide rule, you must first practice reading the scales quickly and accurately. This chapter explains how to read the D scale which is the fundamental scale of the slide rule and is one used most often.

(1) SCALE DIVISIONS

Divisions of the D scale are not uniform and differ as follows.

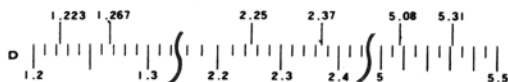
Between 1-2 One division is 0.01

Between 2-4 One division is 0.02

Between 4-10 One division is 0.05

Values between lines can be read by visual approximation.

An actual example is given below.



(2) SIGNIFICANT FIGURES

The D scale is read without regard to decimal point location. For example, 0.237, 2.37, and 237 are read 237 (two three seven) on the D scale. When reading the D scale, the decimal point can be generally ignored and the numbers are directly read as 237 (two three seven). In 237 (two three seven), the 2 (two) is called the first "significant figure."

(3) INDEX LINES

The lines at the left and right ends of the D scale and labeled 1 and 10 respectively are called the "fixed index lines". The corresponding lines on the C scale are called the "slide index lines".

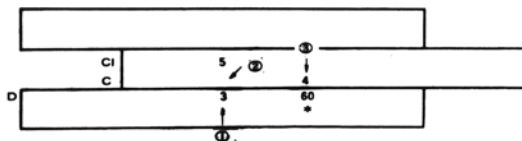
SLIDE RULE DIAGRAM

For the reader's convenience, calculating procedure will be explained in diagram form in this instruction manual. The symbols used in the diagrams are:

Slide Operation		Moving the slide to the position of the arrow with respect to the body of the rule.
Indicator Operation		Setting the hairline of the indicator to the arrow positions on the body and slide.
	*	The position at which the answer is read.

The numeral in the small circle indicates the procedure order. The below diagram shows the slide rule operation required to calculate $3 \times 5 \times 4 = 60$ using the C, D and CI scales.

- (1) Set the hairline over 3 on the D scale.
- (2) Move 5 on the CI scale under the hairline.
- (3) Reset the hairline over 4 on the C scale and read the answer 60 on the D scale under the hairline.



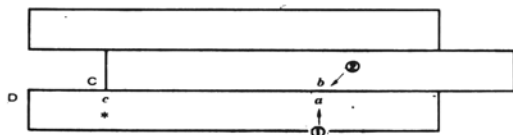
(Note) The vertical lines at both right and left ends of the diagram do not indicate the actual end lines of the slide rule, but only serve to indicate the location of the indices.

CHAPTER 2. MULTIPLICATION AND DIVISION. (1)

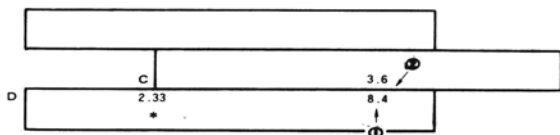
§ 1. DIVISION

FUNDAMENTAL OPERATION (1) $a \div b = c$

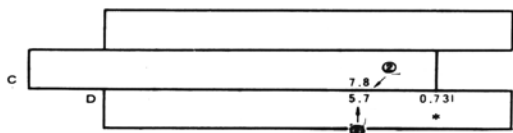
- (1) Set the hairline over a on the D scale,
- (2) Move b on the C scale under the hairline,
read the answer c on the D scale opposite the index of the C scale.



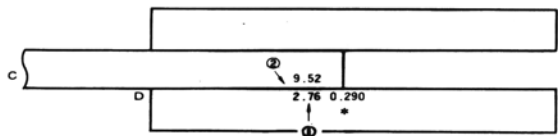
Ex. 2.1 $8.4 \div 3.6 = 2.33$



Ex. 2.2 $5.7 \div 7.8 = 0.731$



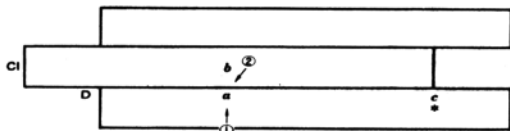
Ex. 2.3 $2.76 \div 9.52 = 0.290$



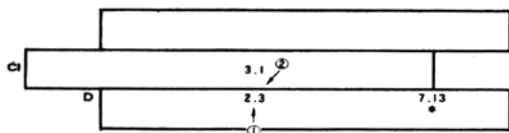
§ 2. MULTIPLICATION

FUNDAMENTAL OPERATION (2) $a \times b = c$

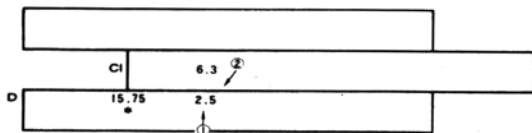
- (1) Set the hairline over a on the D scale,
- (2) Move b on the CI scale under the hairline,
read the answer c on the D scale opposite the index of the CI scale.



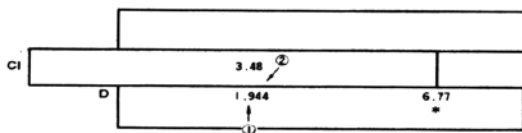
Ex. 2.4 $2.3 \times 3.1 = 7.13$



Ex. 2.5 $2.5 \times 6.3 = 15.75$



Ex. 2.6 $1.944 \times 3.48 = 6.77$



CHAPTER 3 PROPORTION AND INVERSE PROPORTION

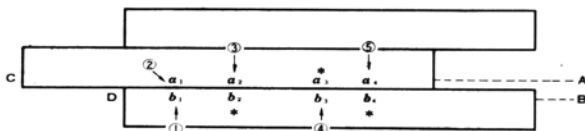
§ 1. PROPORTION

When the slide is set in any position, the ratio of any number on the D scale to its opposite on the C scale is the same as the ratio of any other number on the D scale to its opposite on the C scale. In other words, the D scale is directly proportional to the C scale. This relationship is used to calculate percentages, indices of numbers, conversion of measurements to their equivalents in other systems, etc.

FUNDAMENTAL OPERATION (3) $A \propto B$

A	a_1	a_2	(a_3)	a_4
B	b_1	(b_2)	b_3	(b_4)

() indicates an unknown quantity.

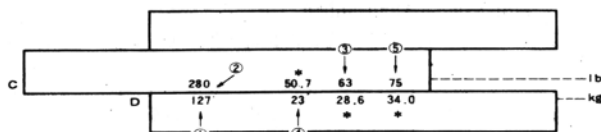


As illustrated in the above figure, when a_1 on the C scale is set opposite b_1 on the D scale the unknown quantities are all found on the C or D scales by moving the hairline.

Ex. 3.1 Conversion.

Given $127 \text{ kg} = 280 \text{ lb}$. Find the values corresponding to the given values.

Pounds	280	63	(50.7)	75
kg	127	(28.6)	23	(34.0)



(Note) In calculating proportion, the C scale must be used for one measurement and the D scale for the other. Interchanging the scales is not permitted until the calculation is completed. In Ex.3.1., the C scale is used for the measurement of pounds and the D scale for that of kilo-grams.

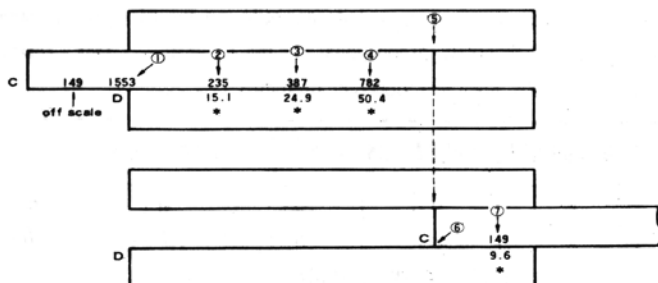
Ex. 3.2 Percentages.

Complete the table below.

Product	A	B	C	D	Total
Sales	235	387	782	149	1553
Percentage	(15.1)%	(24.9)	(50.4)	(9.6)	100

(UNIT: \$10,000,

149 is on the part of the C scale which projects from the slide rule and its opposite on the D scale cannot be read. This is called "off scale". In the case of an "off scale", move the hairline to the right index of the C scale and move the slide to bring the left index of the C scale under the hairline. The answer 9.6 can then be read on the D scale opposite 149 on the C scale which is now inside the rule. This operation is called "interchanging the indices".



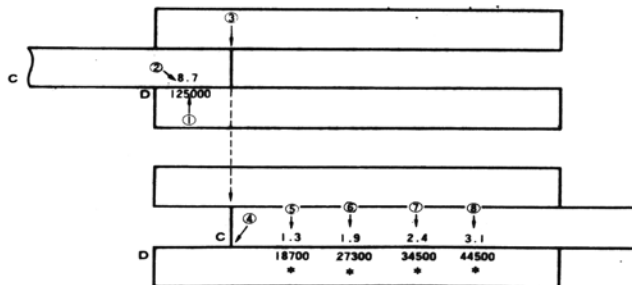
Ex. 3.3 Proportional Distribution.

Distribute a sum of \$125,000 in proportion to each rate specified below.

Rate	1.3	1.9	2.4	3.1	Total (8.7)
Amount	(18,700)	(27,300)	(34,500)	(44,500)	125,000

(UNIT: \$)

When 8.7 on the C scale is set opposite 125000 on the D scale, 1.3, 1.9, 2.4, and 3.1 on the C scale run "off scale". Therefore interchanging the indices is immediately required.



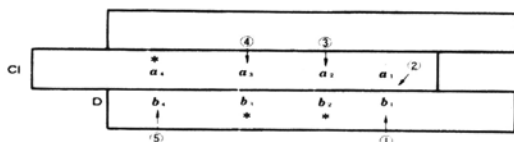
§ 2. INVERSE PROPORTION

When the slide is set in any position, the product of any number on the D scale and its opposite on the CI scale is the same as the product of any other number on the D scale and its opposite on the CI scale. In other words, the D scale is inversely proportional to the CI scale. This relationship is used to calculate inverse proportion problems.

FUNDAMENTAL OPERATION (4) $A \propto \frac{1}{B}$ $A \times B = \text{Constant}$

A	a_1	a_2	a_3	(a_4)
B	b_1	(b_2)	(b_3)	b_4

() indicates an unknown quantity.

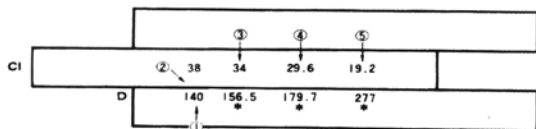


When a_1 on the C scale is set opposite b_1 on the D scale, the product of $a_1 \times b_1$ is equal to that of $a_2 \times b_2$, that of $a_3 \times b_3$, and also equal to that of $a_4 \times b_4$. Therefore, b_2 , b_3 , a_4 can be found by merely moving the hairline of the indicator.

Ex. 3.4

A bicycle runs at 38 km per hour, and takes 140 minutes to go from one town to another. Calculate how many minutes it will take if the bicycle is travelling at 34 km per hour, 29.6 km per hour or 19.2 km per hour.

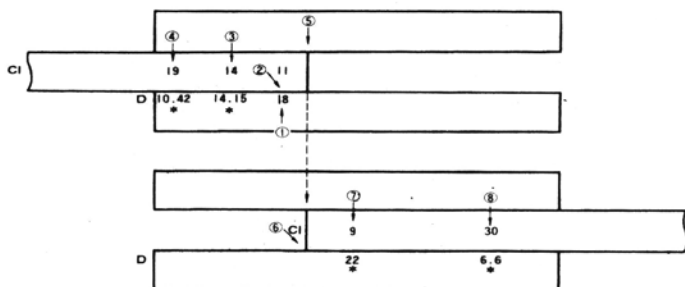
Speed	38 km	34	29.6	19.2
Time required	140 min.	(156.5)	(179.7)	(277)



In solving inverse proportion problems, unlike proportional problems, you can freely switch the scales from one to another, but it is preferable to select and use the scales so that the answer is always read on the D scale. In Ex. 3.1 the answer is always read on the D scale since the given figures are all set on the slide.

Ex. 3.5 A job which requires 11 men 18 days to complete. How many days will it take if the job is done by 9 men, 30 men, 19 men and 14 men?

No. of men	11	9	30	19	14
Time required	18	(22)	(6.6)	(10.42)	(14.15)



In this exercise 9 and 30 run "off scale". In this case it is more efficient to calculate the figures (19 and 14) which are inside the rule before interchanging the indices.

CHAPTER 4. MULTIPLICATION AND DIVISION (2)

§ 1. MULTIPLICATION AND DIVISION OF THREE NUMBERS

Multiplication and division of three numbers are given in the forms of $(a \times b) \times c$, $(a \times b) \div c$, $(a \div b) \times c$ and $(a \div b) \div c$. The part in parentheses is calculated in the manner previously explained and the additional multiplication or division is, usually, performed with one additional indicator operation.

FUNDAMENTAL OPERATION (5) Multiplication and division of three numbers.

(1) $(a \times b) \times c = d$, $(a \div b) \times c = d$

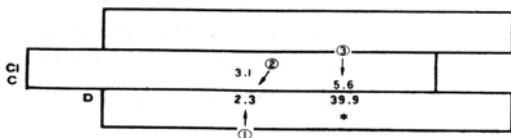
For additional multiplication to follow the calculation $(a \times b)$ or $(a \div b)$, set the hairline over c on the C scale and read the answer d on the D scale under the hairline.

(2) $(a \times b) \div c = d$, $(a \div b) \div c = d$

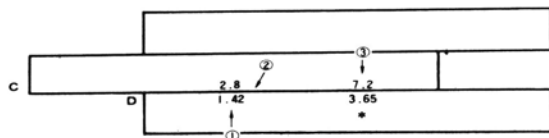
For additional division to follow the calculation $(a \div b)$ or $(a \times b)$, set the hairline over c on the CI scale and read the answer d on the D scale under the hairline.

In multiplication and division of two numbers, you use the CI scale for multiplication and the C scale for division. However, in multiplication and division of three numbers, you must to use the C scale for the additional multiplication and the CI scale for the additional division.

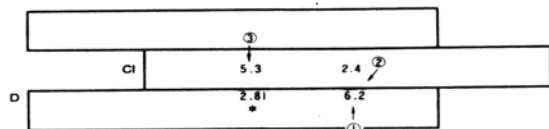
Ex. 4.1 $2.3 \times 3.1 \times 5.6 = 39.9$



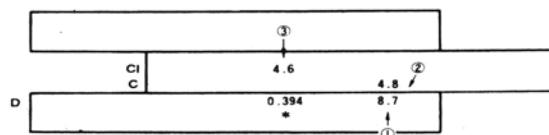
Ex. 4.2 $1.42 \div 2.8 \times 7.2 = 3.65$



Ex. 4.3 $6.2 \times 2.4 \div 5.3 = 2.81$



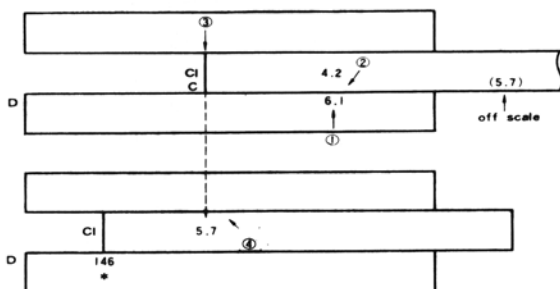
Ex. 4.4 $8.7 \div 4.8 \div 4.6 = 0.394$



§ 2. OFF SCALE

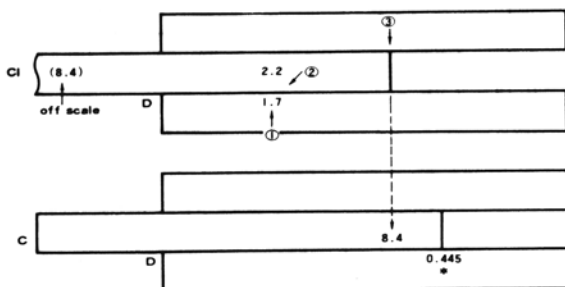
When multiplications and divisions of three numbers are performed by an indicator operation, a position on the C or CI scale over which the hairline is to be set may occasionally run off scale. In this case you once set the hairline over the position on which you read the answer of the first two numbers (opposite the index of the C scale). Then, accomplish the remaining multiplication or division by a slide operation.

Ex. 4.5 $6.1 \times 4.2 \times 5.7 = 146$



The above operations mean that the problem of $a \times b \times c = x$ is solved in such a manner as $a \times b = y$ and $y \times c = x$. Therefore, the third number 5.7 is to be set on the CI scale basing on the principle of multiplication and division of two numbers. If the third operation is a division as the problem of Ex. 4.6, set the third number on the C scale.

Ex. 4.6 $1.7 \times 2.2 \div 8.4 = 0.445$

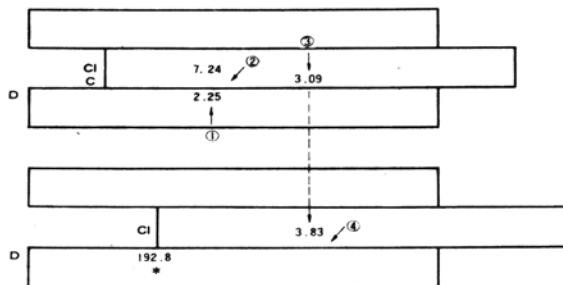


§ 3. MULTIPLICATION AND DIVISION OF MORE THAN FOUR NUMBERS.

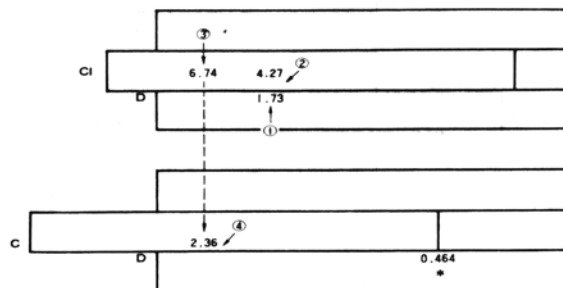
When the multiplication and division of three numbers, such as $a \times b \times c = d$ is completed, the answer (d) is found under the hairline on the D scale.

Using this value of d on the D scale you can start for further multiplications or divisions by slide operation and indicator operation. Multiplications and divisions of four or more numbers are calculated by alternative operations of slide-indicator. When a problem of multiplication or division of four or more numbers is given, you will select a better procedure order of calculations to minimize the distance the slide must be moved as well as to avoid the off scale.

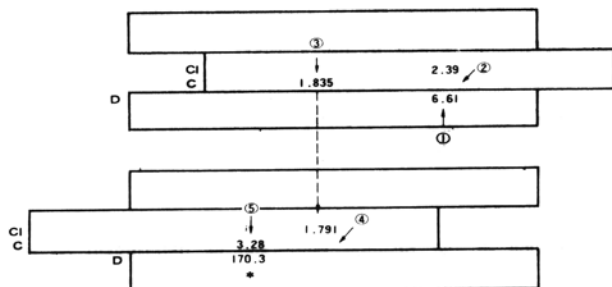
Ex. 4.7 $2.25 \times 7.24 \times 3.09 \times 3.83 = 192.8$



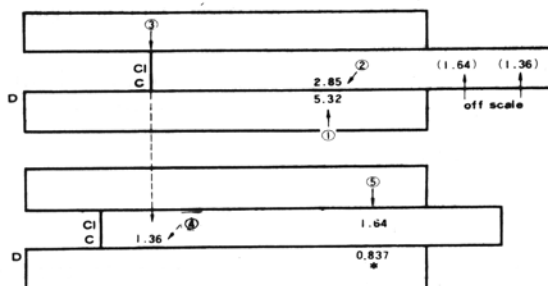
Ex. 4.8 $\frac{1.73 \times 4.27}{6.74 \times 2.36} = 0.464$



Ex. 4.9 $6.61 \times 2.39 \times 1.835 \times 1.791 \times 3.28 = 170.3$



Ex. 4.10 $\frac{5.32}{1.36 \times 1.64 \times 2.85} = 0.837$



§4. PLACING THE DECIMAL POINT

Since slide rule calculations of multiplication and division problems yield only the significant figures of the answer, it is necessary to determine the proper location of the decimal point before the problem is completed. There are many methods used to properly place the decimal point. Several of the most popular will be described here.

(a) Approximation

The location of the decimal point can be determined by comparing the significant figures given by the slide rule and the product calculated mentally by rounding off.

$$\text{Ex. } 25.3 \times 7.15 = 180.9$$

To get an approximate value $25.3 \times 7.15 \rightarrow 30 \times 7 = 210$. Since the significant figures are read 1809 (one · eight · zero · nine) given by the slide rule, the correct answer must be 180.9.

To get an approximate value from multiplication and division of three and more factors may be difficult. In this case, the following method can be employed.

(i) Moving the decimal point

$$\text{Ex. } \frac{285 \times 0.00875}{13.75} = 0.1814$$

Divide 285 by 100 to obtain 2.85 and, at the same time, multiply 0.00875 by 100 to obtain 0.875. In other words, the decimal point of 285 is moved two places to the left and that of 0.00875 is moved two places to the right, therefore, the product of 285 times 0.00875 is not affected.

$$\frac{285 \times 0.00875}{13.75} \text{ is rewritten to } \frac{2.85 \times 0.875}{13.75} \text{ and approximated to } \frac{3 \times 0.9}{10} = 0.27.$$

Since you read 1814 (one eight one four) on the slide rule, the answer must be 0.1814.

Ex. $\frac{1.346}{0.00265} = 508$

$$\frac{1.346}{0.00265} \rightarrow \frac{1346}{2.65} \rightarrow \frac{1000}{3} \rightarrow 300$$

(ii) Reducing fractions

If a number in the numerator has a value close to that of a number in the denominator, they can be cancelled out and an approximate figure is obtained.

Ex. $\frac{1.472 \times 9.68 \times 4.76}{1.509 \times 2.87} = 15.66$

$$\frac{\cancel{1.472} \times \overset{3}{\cancel{9.68}} \times 4.76}{\cancel{1.509} \times \cancel{2.87}} \rightarrow 3 \times 5 = 15$$

1.472 in the numerator can be considered to be equal to 1.509 in the denominator and they can therefore be cancelled out. 9.68 in the numerator is approximately 9 and 2.87 in the denominator is approximately 3. 4.76 in the numerator is approximately 5. Using the slide rule, you read 1566 on the D scale, therefore, the answer must be 15.66

(iii) Combination of (i) and (ii)

Ex. $\frac{7.66 \times 0.423 \times 12.70}{0.641 \times 3.89} = 16.50$

$$\frac{7.66 \times \overset{1}{\cancel{0.423}} \times 12.70}{\overset{1}{\cancel{0.641}} \times 3.89} \rightarrow \frac{\cancel{7.66} \times \cancel{4.23} \times 12.70}{\cancel{6.41} \times \cancel{3.89}} \rightarrow 13$$

The decimal point of 0.423 and 0.641 in the numerator is shifted one place to the right. The approximate numbers in the denominator and numerator are cancelled and the answer, which is approximately 13, is found.

(b) Exponent

Any number can be expressed as $N \times 10^p$ where $1 \leq N < 10$.

This method of writing numbers is useful in determining the location of the decimal point in difficult problems involving combined operations.

$$\text{Ex. } \frac{1587 \times 0.0503 \times 0.381}{0.00815} = 3730$$

$$\begin{aligned} \frac{1587 \times 0.0503 \times 0.381}{0.00815} &= \frac{1.587 \times 10^3 \times 5.03 \times 10^{-2} \times 3.81 \times 10^{-1}}{8.15 \times 10^{-3}} \\ &= \frac{1.587 \times 5.03 \times 3.81}{8.15} \times 10^{3-2-1-(-3)} \\ &= \frac{2 \times 5 \times 4}{8} \times 10^{3-2-1-(-3)} = 5 \times 10^3 = 5000 \end{aligned}$$

CHAPTER 5. SQUARES AND SQUARE ROOTS

The "place number" is used to find squares and square roots as well as placing the decimal point of squares and square roots.

When the given number is greater than 1, the place number is the number of digits to the left of the decimal point. When the given number is smaller than 1, the place number is the number of zeros between the decimal point and the first significant digit but the sign is minus.

For example, the place number of 2.97 is 1, of 29.7 is 2, of 2970 is 4, and of 0.0297 is -1. The place number of 0.297 is 0.

§ 1. SQUARES AND SQUARE ROOTS

The A scale, which is identical to the B scale, consists of two D scales connected together and reduced to exactly $1/2$ of their original length. The A scale is used with the C, D or CI scale to perform the calculations of the square and square root of numbers.

Since they consist of two D scales, the A and B scales are called "two cycle scales" whereas the fundamental C, D and CI scales are called "one cycle scales"

FUNDAMENTAL OPERATION (6) x^2 $\sqrt{y}$

- (1) When the hairline is set over x on the D scale, x^2 is read on the A scale under the hairline.
- (2) When the hairline is set over y on the A scale, $\sqrt{y}$ is read on the D scale under the hairline.

A	x^2	y
	↑	↓
D	x	$\sqrt{y}$

The location of the decimal point of the square read on the A scale is determined using the place number as follows:

- a) When the answer is read on the left half section of the A scale (1~10), the "place number" of $x^2 = 2$ ("place number" of x) - 1
- b) When the answer is read on the right half section of the A scale (10~100), the "place number" of $x^2 = 2$ ("place number" of x)

Ex. 5.1 $172^2 = 29600$ The place number of 172 is 3.
Hence, the place number in the answer is $2 \times 3 - 1 = 5$

$17.2^2 = 296$ The place number of 17.2 is 2.
Hence, the place number in the answer is $2 \times 2 - 1 = 3$

$0.172^2 = 0.0296$ The place number of 0.172 is 0
Hence, the place number in the answer is $2 \times 0 - 1 = -1$

Ex. 5.2 $668^2 = 446000$ The place number of 668 is 3
 $= 4.46 \times 10^5$ Hence, the place number in the answer is $2 \times 3 - 6$

$0.668^2 = 0.446$ The place number of 0.668 is 0
Hence, the place number in the answer is $2 \times 0 = 0$

$0.0668^2 = 0.00446$ The place number of 0.0668 is -1
Hence, the place number in the answer is $2 \times (-1) = -2$

A	$\bullet$ 2.96	$\bullet$ 44.6
	↑	↑
	D 1.72	6.68

When the hairline is set over x on the A scale, $\sqrt{x}$ appears under the hairline on the D scale. Since the A scale consists of two identical sections, only the correct section can be used. Set off the number whose square root is to be found into two digits groups from the decimal point toward the first significant figure of the number. If the group in which the first significant figure appears has only one digit (the first significant digit only), use the left half of the A scale. If it has two digits (the first significant digit and one more digit), use the right half of the A scale.

- Ex. 5.3 21|80|00 (right half) Place number.....3 $\sqrt{218000} = 467$
 2|18|00 (left half) Place number.....3 $\sqrt{21800} = 147.7$
 21|80 (right half) Place number.....2 $\sqrt{2180} = 46.7$
 2|18 (left half) Place number.....2 $\sqrt{218} = 14.77$
 0.21|8 (right half) Place number.....0 $\sqrt{0.218} = 0.467$
 0.02|18 (left half) Place number.....0 $\sqrt{0.0218} = 0.1477$
 0.00|21|8 (right half) Place number....1 $\sqrt{0.00218} = 0.0467$
 0.00|02|18 (left half) Place number....1 $\sqrt{0.000218} = 0.01477$

A	↓ 2.18	↓ 21.8
D	1.477 *	4.67 *

§ 2. MULTIPLICATION AND DIVISION INVOLVING THE SQUARE AND SQUARE ROOT

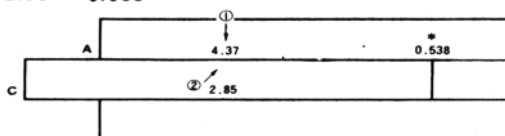
Basically, the A scale is the same logarithm scale as the D scale. Therefore, you can use the A and B scales for multiplication and division in the same manner as you use the C, D and CI scales.

FUNDAMENTAL OPERATION (7)

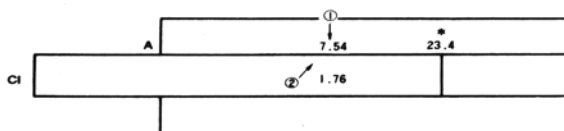
Multiplication and division involving squares

- (1) Set the number to be squared on the one cycle scale (C, D, or CI) and the number not to be squared on the two cycle scale (A or B)
- (2) Read the answer on the A scale.

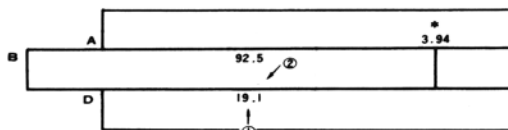
Ex. 5.4 $4.37 \div 2.85^2 = 0.538$



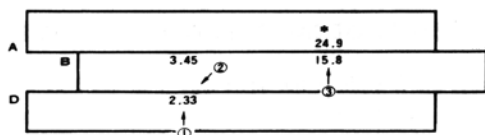
Ex. 5.5 $7.54 \times 1.76^2 = 23.4$



Ex. 5.6 $19.1^2 \div 92.5 = 3.94$



Ex. 5.7 $\frac{2.33^2 \times 15.8}{3.45} = 24.9$



(Note) In multiplication or division involving squares, you can freely use either half section of the A or B scale to minimize the distance the slide must be moved.

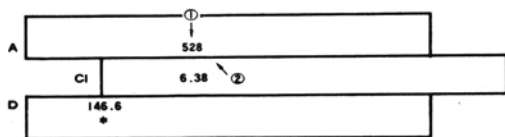
FUNDAMENTAL OPERATION (8)

Multiplication and division involving the square roots of numbers.

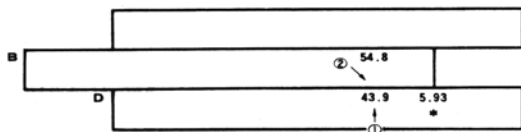
- (1) The number whose square root is to be found should always be set on the two cycle scale (A or B), and the number whose square root is not to be found should be set on the one cycle scale (C, D or CI).
- (2) Read the answer on the D scale.

In multiplication and division which involve the square roots of numbers, the correct section of the A scale must be used. The correct section of the A scale to be used can be determined in the manner previously described.

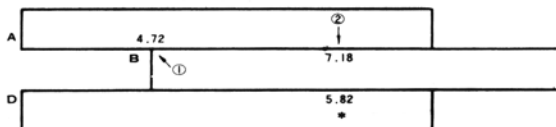
Ex. 5.8 $\sqrt{528} \times 6.38 = 146.6$



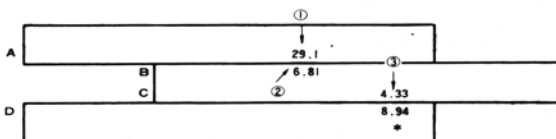
Ex. 5.9 $43.9 \div \sqrt{54.8} = 5.93$



Ex. 5.10 $\sqrt{4.72 \times 7.18} = 5.82$



Ex. 5.11 $\frac{\sqrt{29.1 \times 4.33}}{\sqrt{6.81}} = 8.94$

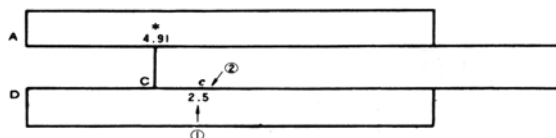


§ 3. THE AREA OF A CIRCLE

A gauge mark "c" is imprinted on the C scale at the 1.128 position. This is used with the D scale to find the area of a circle.

When you set the gauge mark "c" on the C scale opposite the diameter set on the D scale, the area of the circle is read on the A scale opposite the index of the C scale.

Ex. 5.12 Find the area of a circle having a diameter of 2.5cm.



Answer 4.91cm²

CHAPTER 6. CUBE AND CUBE ROOT.

The K and K' scales consist of three D scales connected and reduced to exactly $1/3$ of their original length. They are called "three cycle logarithmic scales" and are used to calculate cubes and cube roots. The K' scale, developed especially for this slide rule, permits efficient multiplications and divisions involving cubes and cube roots, and is a very useful scale for calculations arising from Manning's Hydrometric Law covered in a later part of this manual.

§1. CUBE AND CUBE ROOT.

FUNDAMENTAL OPERATION (9) x^3 , $\sqrt[3]{y}$

- (1) When the hairline is set over x on the D scale, x^3 is read on the K scale.
- (2) When the hairline is set over y on the K scale, $\sqrt[3]{y}$ is read on the D scale.

K	x^3	y
	↑	↓
D	x	$\sqrt[3]{y}$

The location of the decimal point in the answer found on the K scale is determined by using the place number as follows:

- a. When the answer is read on the left section (1 ~ 10) of the K scale, (place number of x) $\times 3 - 2$ = Place number of the answer x^3
- b. When the answer is read on the center section (10 ~ 100) of the K scale, (Place number of x) $\times 3 - 1$ = Place number of the answer x^3
- c. When the answer is read on the right section (100 ~ 1000) of the K scale, (Place number of x) $\times 3$ = Place number of the answer x^3

Ex. 6.1 Find the cube of the following numbers:

$$16.3^3 = 4330 \quad (\text{Place number of cubes} = 2 \times 3 - 2 = 4)$$

$$0.163^3 = 0.00433 \quad (\text{Place number of cubes} = 0 \times 3 - 2 = -2)$$

$$273^3 = 20400000 \quad (\text{Place number of cubes} = 3 \times 3 - 1 = 8) \\ = 2.04 \times 10^7$$

$$0.0273^3 = 0.0000204 \quad (\text{Place number of cubes} = -1 \times 3 - 1 = -4) \\ = 2.04 \times 10^{-5}$$

$$72.3^3 = 378000 \quad (\text{Place number of cubes} = 2 \times 3 = 6) \\ = 3.78 \times 10^5$$

$$0.00723^3 = 0.000000378 \quad (\text{Place number of cubes} = -2 \times 3 = -6) \\ = 3.78 \times 10^{-7}$$

K	4.33	20.4	378
	↑	↑	↑
	1.63	2.73	7.23

The cube root $\sqrt[3]{x}$ is read on the D scale opposite x on the K scale. Since the K scale consists of three identical sections: the left, the center, and the right, the number x must be set on the proper section of the K scale. To determine the proper section, mark off the number in groups of three digits beginning at the decimal point and moving toward the first significant digit. If the group in which the first significant figure appears contains only one digit, use the left part; if it contains two digits, use the center part, and if the group contains three digits, use the right part of the K scale. The place number of the answer is the place number of the group which contains the first significant digit.

Ex. 6.2 $673|000$ (Right) Place number of answer... $2 \sqrt[3]{673000} = 87.7$

$67|300$ (Center) Place number of answer... $2 \sqrt[3]{67300} = 40.7$

$6|730$ (Left) Place number of answer... $2 \sqrt[3]{6730} = 18.88$

$0.673|$ (Right) Place number of answer... $0 \sqrt[3]{0.673} = 0.877$

$0.067|3$ (Center) Place number of answer... $0 \sqrt[3]{0.0673} = 0.407$

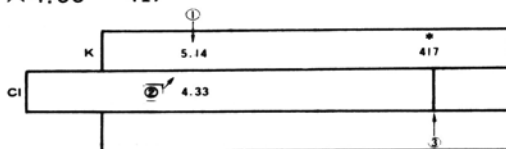
0.006173 (Left) Place number of answer... 0 $\sqrt[3]{0.00673}=0.1888$
 0.0001673 (Right) Place number of answer... -1 $\sqrt[3]{0.000673}=0.0877$

K	6.73	67.3	673
	↓	↓	↓
D	1.888 *	4.07 *	8.77 *

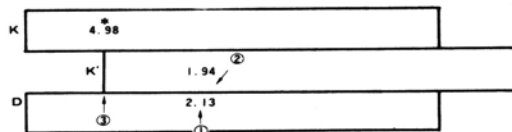
§2. MULTIPLICATION AND DIVISION INVOLVING CUBES, CUBE ROOTS.

Multiplication and division involving cube are performed in the same manner as Fundamental operation (7) Multiplication and division involving cube root are performed in the same manner as Fundamental Operation (8).

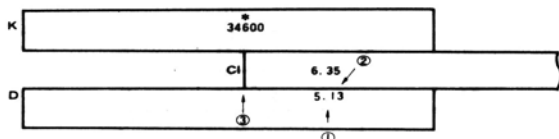
Ex. 6.3 $5.14 \times 4.33^3 = 417$



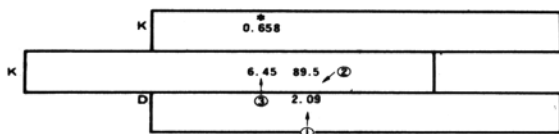
Ex. 6.4 $2.13^3 \div 1.94 = 4.98$



Ex. 6.5 $(5.13 \times 6.35)^3 = 34600$

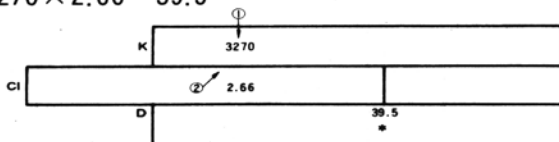


Ex. 6.6 $\frac{2.09^3 \times 6.45}{89.5} = 0.658$

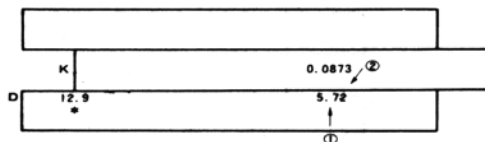


6.45 is to be set on the left part of the K' scale, however in this example, it is set on the center part to avoid an off-scale. In multiplications and divisions involving cubes, a number can be set on any part of either K or K' scale. However in multiplications and divisions involving cube roots, the correct part of the K and K' scales must be used.

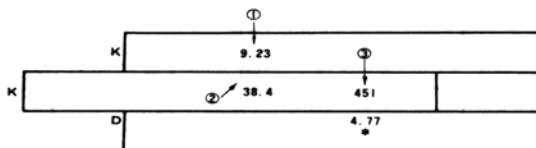
Ex. 6.7 $\sqrt[3]{3270} \times 2.66 = 39.5$



Ex. 6.8 $5.72 \div \sqrt[3]{0.0873} = 12.9$

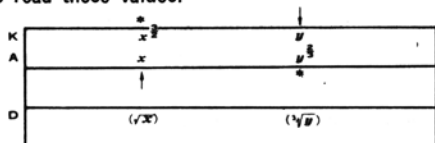


Ex. 6.9 $\sqrt[3]{\frac{9.23 \times 451}{38.4}} = 4.77$



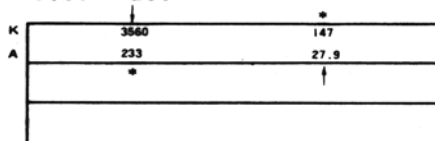
§ 3. $\frac{3}{2}$ POWERS AND $\frac{2}{3}$ POWERS

The A and K scales are utilized to find either the $\frac{3}{2}$ power, or $\frac{2}{3}$ power of a number and since both of these scales are on the frame of the slide rule, only the hairline is used to read these values.

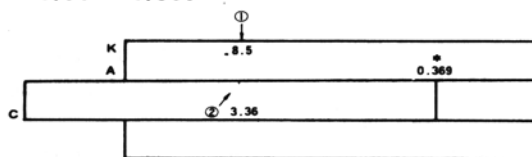


To determine the place number of $x^{\frac{3}{2}}$, first determine the place value of $\sqrt{x}$ and then apply the rule to determine the place value of the cube of this number. The place value of $y^{\frac{2}{3}}$ is found by first finding the place value of $\sqrt[3]{y}$ and then using the rule to determine the place value of the square of this number.

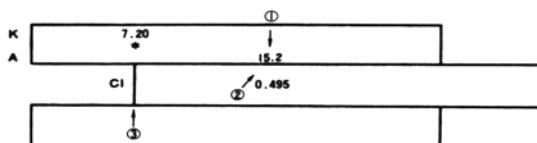
Ex. 6.10 $27.9^{\frac{3}{2}} = 147$ $3560^{\frac{2}{3}} = 233$



Ex. 6.11 $8.5^{\frac{2}{3}} \div 3.36^2 = 0.369$



Ex. 6.12 $15.2^{\frac{3}{2}} \times 0.495^3 = 7.20$



CHAPTER 7. FOURTH POWER AND FOURTH ROOT.

The F scale of this slide rule is a four cycle logarithmic scale; therefore it can be used with the D scale to calculate 4th powers and 4th roots of a number cooperated. The F scale is unique and simplifies calculation of Manning's equation (hydraulics) the same as the K' scale.

§1. 4TH POWER AND 4TH ROOT.

The place number of x^4 can be determined in the following manner.

- When the answer is read on the left section (1~10.) of the F scale, (place number of x) $\times 4 - 3$ = place number of the answer x^4 .
- When the answer is read on the center left section (10~100) of the F scale, (place number of x) $\times 4 - 2$ = place number of the answer x^4 .
- When the answer is read on the center right section (100~1000) of the F scale, (place number of x) $\times 4 - 1$ = place number of the answer x^4 .
- When the answer is read on the right section (1000~10000) of the F scale, (place number of x) $\times 4$ = place number of the answer x^4 .

Ex. 7.1 Find the 4th powers of the following numbers:

$$145.5^4 = 449000000 \quad (\text{place number of the answer} = 3 \times 4 - 3 = 9) \\ = 4.49 \times 10^8$$

$$0.1455^4 = 0.000449 \quad (\text{place number of the answer} = 0 \times 4 - 3 = -3)$$

$$23.5^4 = 305000 \quad (\text{place number of the answer} = 2 \times 4 - 2 = 6) \\ = 3.05 \times 10^5$$

$$0.235^4 = 0.00305 \quad (\text{place number of the answer} = 0 \times 4 - 2 = -2)$$

$$0.0411^4 = 0.0000285 \quad (\text{place number of the answer} = -1 \times 4 - 1 = -5) \\ = 2.85 \times 10^{-6}$$

$$90.5^4 = 6710000 \quad (\text{place number of the answer} = 2 \times 4 = 8) \\ = 6.71 \times 10^7$$

F	4.49	30.5	285	6710
D	1.455	2.35	4.11	9.05
	↑	↑	↑	↑

The 4th root, $\sqrt[4]{x}$ is read on the D scale opposite x on the F scale. Since the F scale consist of four identical sections: the left, the center left, the center right, and the right sections. To find the fourth root of a number, it must be set on the proper section of the F scale. To determine the proper section, first set off the number (x) into groups of four digits beginning at the decimal point and moving toward the first significant figure. If the group in which the first significant figure appears contains only one digit, use the left section, if it contains two digits, use the center left, if the group contains three digits, use the center right; and if the group contains four digits, use the right section. The place number of the answer is the place number of containing the first significant figure.

Ex. 7.2

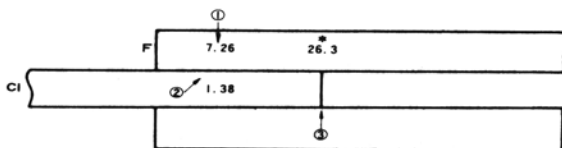
- 1|4700|0000 (left)place number of the answer 3 $\sqrt[4]{147000000}=110.1$
 1470|0000 (right)place number of the answer 2 $\sqrt[4]{14700000}=61.9$
 147|0000 (center right).....place number of the answer 2 $\sqrt[4]{1470000}=34.8$
 14|7000 (center left).....place number of the answer 2 $\sqrt[4]{147000}=19.58$
 0.0147| (center right).....place number of the answer 0 $\sqrt[4]{0.0147}=0.348$
 0.0014|7 (center left).....place number of the answer 0 $\sqrt[4]{0.00147}=0.1958$
 0.0001|47 (left)place number of the answer 0 $\sqrt[4]{0.000147}=0.1101$
 0.0000|147 (right)place number of the answer -1 $\sqrt[4]{0.0000147}=0.0619$

F	1.47	14.7	147	1470
	↓	↓	↓	↓
D	1.101	1.958	3.48	6.19
	*	*	*	*

§2. MULTIPLICATION AND DIVISION INVOLVING 4TH POWER AND 4TH ROOT.

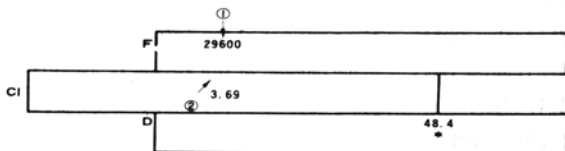
The F scale permits multiplication and division involving 4th powers and 4th roots.

Ex. 7.3 $7.26 \times 1.38^4 = 26.3$



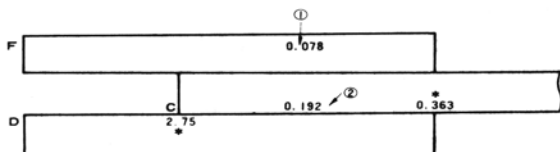
- (Note) 1. It is a basic rule that the result of multiplication and division involving 4th power is read on the F scale and multiplication and division involving 4th root is read on the D scale.
2. To divide by the 4th power, the C scale is used instead of CI scale.
3. To calculate $a^4 \div b$, first find a^4 on the F scale, and reset it on the D scale and divide it by b using the C scale.

Ex. 7.4 $\sqrt[4]{29600} \times 3.69 = 48.4$



(Note) In calculations involving 4th root only the correct section of the F scale must be used (the left, center left, center right or right sections). However, for calculations involving 4th powers any section of the F scale can be used.

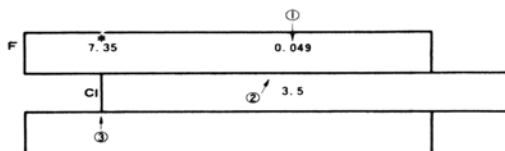
Ex. 7.5 $\sqrt[4]{0.078} \div 0.192 = 2.75$
 $0.192 \div \sqrt[4]{0.078} = 0.363$



As illustrated above, for any position of the slide; the value on the D scale opposite the index of the C scale is reciprocal to the value on the C scale opposite the index of the D scale.

Ex. 7.6 Find the principal moment of inertia of area of a circle having a diameter of 3.5cm.

$$I = \frac{\pi d^4}{(64)} = 0.049 d^4$$



Answer $7.35d^4$

CHAPTER 8. LOGARITHMS AND EXPONENTS

§ 1. COMMON LOGARITHMS

The L scale, which is a uniformly divided scale, is used with the D scale to find mantissa of common logarithms. The characteristic of the logarithm is found by the place number of the given number. If the place number of the given number is m , the characteristic of the common logarithm found on the D scale is $m - 1$.

FUNDAMENTAL OPERATION (10) $\log_{10} x$, $\text{antilog}_{10} y$ (10^y)

- (1) When the hairline is set over x on the D scale, $\log_{10} x$ is read under the hairline on the L scale.
- (2) When the hairline is set over the mantissa of y on the L scale, the significant digits of $\text{antilog}_{10} y$ is read under the hairline on the D scale.

L	$\log_{10} x$	y
	↑	↓
D	x	$\log_{10} y$

Ex. 8.1 (1) $\log_{10} 2.56 = 0.408$
 $\log_{10} 256 = 2.408$
 $\log_{10} 0.0256 = \bar{2}.408$

(2) $\text{antilog}_{10} 0.657 = 4.54$
 $\text{antilog}_{10} 1.657 = 45.4$
 $\text{antilog}_{10} 1.657 = 0.454$

L	0.408	0.657
	↑	↓
D	2.56	4.54

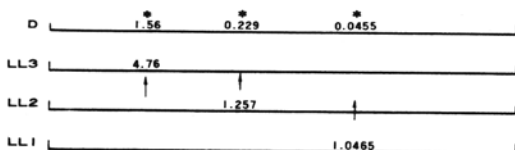
§2. NATURAL LOGARITHMS

The log log scales LL1, LL2 and LL3 are called the LL scales and are used to obtain the natural logarithm of a numbers and powers and roots of numbers from 1.01 to 22,000. The LL scales are read with the location of the decimal point and these numbers either smaller than 1.01 or larger than 22,000 can not be direct obtained on the log log scales.

(a) HOW TO FIND NATURAL LOGARITHMS

When the hairline is set over x on the LL scale, $\log_e x$ appears on the D scale.

Ex. $8.2^* \log_e 4.76 = 1.56 \quad \log_e 1.257 = 0.229 \quad \log_e 1.0465 = 0.0455$

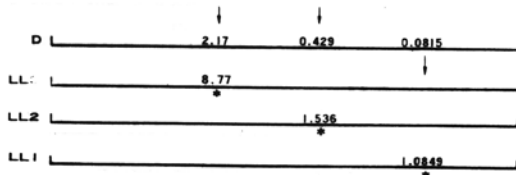


The relationship between the place number of the natural logarithm and the number (1, 2, 3) of the LL scale can be seen from the above illustration.

(b) FINDING e^x

e^x is found on the LL scale when the hairline is set over x on the D scale.

Ex. 8.3 $e^{2.17} = 8.77 \quad e^{0.429} = 1.536 \quad e^{0.0815} = 1.0849$



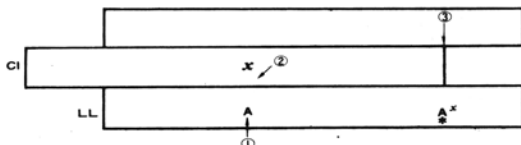
For calculating e^{-x} , first find e^x and then find $(\frac{1}{e^x})$ by using the D and DI scales.

§ 3. EXPONENT

FUNDAMENTAL OPERATION (11) A^x

- (1) Set the hairline over A on the LL scale.
- (2) Move x on the CI scale under the hairline.

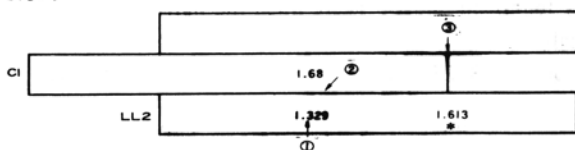
Read the answer on the LL scale opposite the index of the CI scale.



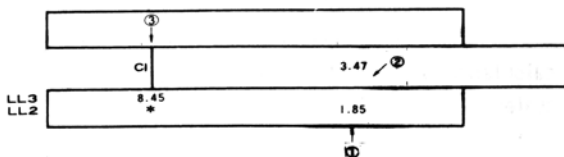
Since the slide rule has three LL scales, you must find on what LL scale the answer will appear. In the calculation of A^x , if x is a number between 1~10, the LL scale on which the answer appears will be determined as follows.

- (1) When the slide protrudes to the left, use the LL scale having the same number as the LL scale on which A is set.
- (2) When the slide protrudes to the right, use the LL scale 1 number higher than the LL scale on which A is set.

Ex. 8.4 $1.329^{1.68} = 1.613$



Ex. 8.5 $1.85^{3.47} = 8.45$



In calculating A^{-x} , find A^x first and then obtain the reciprocal $\frac{1}{A^x}$ as the answer

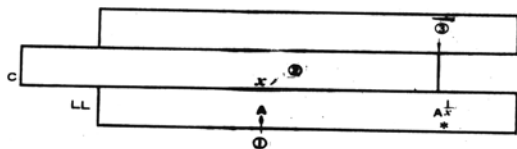
Ex. 8.6 $0.872^{2.6} = 0.700$

This problem can be converted to $\left(\frac{1}{0.872}\right)^{2.6}$ and calculated in the following manner.

- (1) Find $\frac{1}{0.872} = 1.147$ (The D and DI scales are used)
- (2) Find $1.147^{2.6} = 1.428$ (The LL and CI scales are used)
- (3) Find $\frac{1}{1.428} = 0.700$ (The D and DI scales are used)

FUNDAMENTAL OPERATION (12) $A^{\frac{1}{x}}$

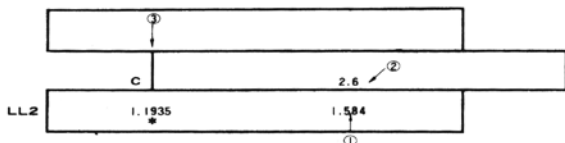
- (1) Set the hairline over A on the LL scale.
- (2) Move x on the C scale under the hairline. Read the answer on the LL scale opposite the index of the C scale.



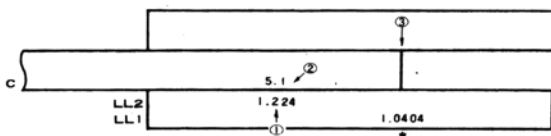
In calculating $A^{\frac{1}{x}}$, where x is a number between 1 and 10, the LL scale on which the answer appears will be determined as follows.

- (1) If the slide protrudes to the right, the answer is found on the LL scale having the same number as the LL scale on which A is set.
- (2) If the slide protrudes to the left, the answer is found on the LL scale one number lower than the LL scale on which A is set.

Ex. 8.7 $1.584^{\frac{1}{2.6}} = 1.1935$



Ex. 8.8 $1.224^{\frac{1}{5.1}} = 1.0404$



To calculate $A^{\frac{1}{x}}$, first calculate $A^{\frac{1}{x}}$ and then find its reciprocal $\frac{1}{A^{\frac{1}{x}}}$ as the answer.

Ex. 8.9 $0.165^{\frac{1}{3.7}} = 0.615$

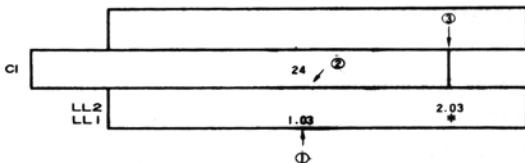
This problem is rewritten to $\frac{1}{(\frac{1}{0.165})^{\frac{1}{3.7}}}$ and then calculated in the following manner.

Find $\frac{1}{0.165} = 6.06$ (The D and DI scales are used)

Find $6.06^{\frac{1}{3.7}} = 1.627$ (The LL and C scales are used)

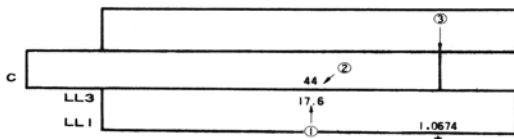
Find $\frac{1}{1.627} = 0.615$ as the answer (The D and DI scales are used)

Ex. 8.10 $1.03^{24} = 2.03$



In calculating $1.03^{24} = 2.03$ since 24 is larger than 10, 1.03^{24} is rewritten to $1.03^{2.4 \times 10} = (1.03^{2.4})^{10}$ and read the answer 2.03 on the LL2 scale opposite the position you can read the answer of $1.03^{2.4}$ on the LL1 scale. It is based on the principle that any number on the LL2 scale is the 10th power of the LL1 scale and any number on the LL3 scale is the 10th power of the LL2 scale.

Ex. 8.11 $17.6^{\frac{1}{44}} = 1.0674$



CHAPTER 9. TRIGONOMETRIC FUNCTIONS

The S scale is used to find the sine of an angle. The T scale is used to find the tangent of an angle. These scales are graduated in degrees and minutes and read from left to right using the black numbers and from right to left using the red numbers.

§ 1. SINE, TANGENT, COSINE

FUNDAMENTAL OPERATION (13) $\sin \theta$, $\tan \theta$

When the slide is closed, and

- (1) The hairline is set over θ on the S scale, $\sin \theta$ is read under the hairline on the D scale.
- (2) When the hairline is set over θ on the T scale, $\tan \theta$ is read under the hairline on the D scale.

T	θ	
S		θ
D	$\tan \theta$ *	$\sin \theta$ *

The scales are read from left to right using the black numbers.

Ex. 9.1 (1) $\sin 13^\circ 40' = 0.236$ (2) $\tan 23^\circ 50' = 0.441$

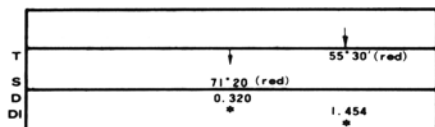
T		$23^\circ 50'$
S	$13^\circ 40'$	
D	0.236 *	0.441 *

When the T scale is read from left to right using the black numbers angles from 0° to 45° are covered. To find the tangent of angles greater than 45° use the red numbers, the answer is found directly on the DI scale.

When finding the cosine, the red numbers of the S scale are used basing

on the relation $\cos \theta = \sin (90^\circ - \theta)$ and the answer is read on the D scale.

Ex. 9.2 (1) $\tan 55^\circ 30' = 1.454$ (2) $\cos 71^\circ 20' = 0.320$

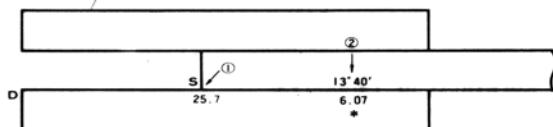


$\cot \theta$, $\sec \theta$ and $\operatorname{cosec} \theta$ are found to be reciprocal of $\tan \theta$, $\cos \theta$ and $\sin \theta$ respectively. Since a value under the hairline on the D scale is the reciprocal of the value under the hairline on the DI scale, this relationship can be conveniently used.

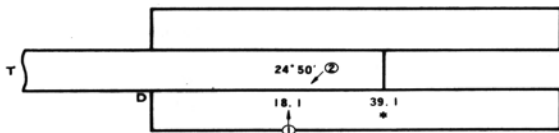
§ 2. MULTIPLICATION AND DIVISION INVOLVING TRIGONOMETRIC FUNCTIONS

The following example illustrates the operations performing calculations involving trigonometric functions.

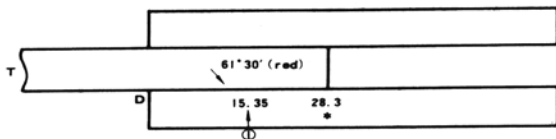
Ex. 9.3 $25.7 \times \sin 13^\circ 40' = 6.07$



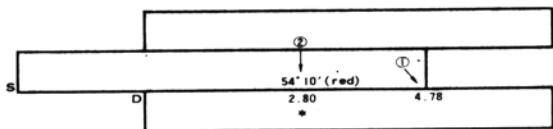
Ex. 9.4 $18.1 \div \tan 24^\circ 50' = 39.1$



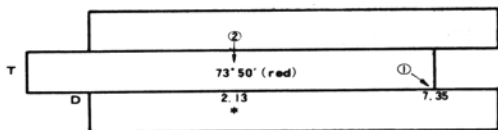
Ex. 9.5 $15.35 \times \tan 61^\circ 30' = 28.3$



Ex. 9.6 $4.78 \times \cos 54^\circ 10' = 2.80$



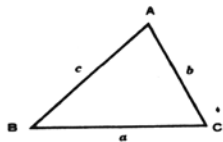
Ex. 9.7 $7.35 \times \cot 73^\circ 50' = 2.13$



§ 3. SOLUTIONS OF TRIANGLES

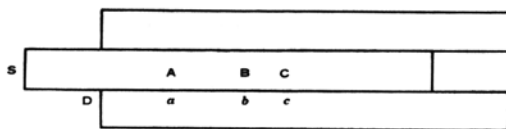
FUNDAMENTAL OPERATION (14) THE LAW OF SINES

Given the triangle ABC, a is the side corresponding to A , b is the side corresponding to B , and c to C .



The law of sines is

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$

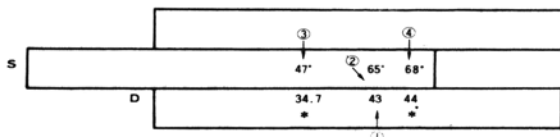
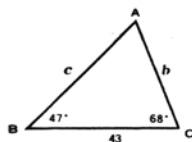


We can solve any triangle using the method solving proportion problems, when a side and its corresponding angle and another part are given.

Ex. 9.8 Find b and c .

$$\begin{aligned}\angle A &= 180^\circ - (47^\circ + 68^\circ) \\ &= 65^\circ\end{aligned}$$

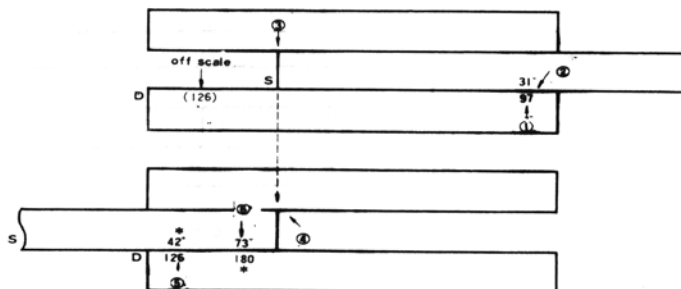
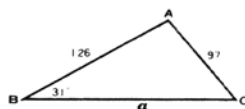
Answer $b = 34.7$ $c = 44.0$



Ex. 9.9 Find $\angle A$, $\angle C$ and a .

$$\angle A = 180^\circ - (31^\circ + 42^\circ) = 107^\circ$$

Answer $\angle A = 107^\circ$ $\angle C = 42^\circ$ $a = 180$

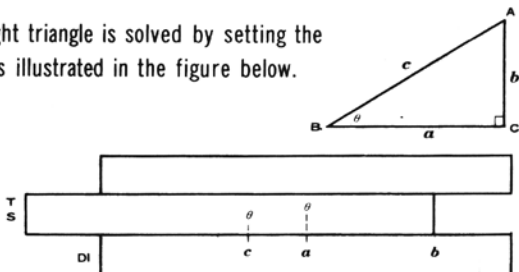


$\angle A$ is found as 107° , which is not shown on the S scale. In this case, the complementary angle $180^\circ - 107^\circ = 73^\circ$ is set on the S scale basing on a relation $\sin \theta = \sin (180^\circ - \theta)$.

§ 4. SOLUTION OF RIGHT TRIANGLES

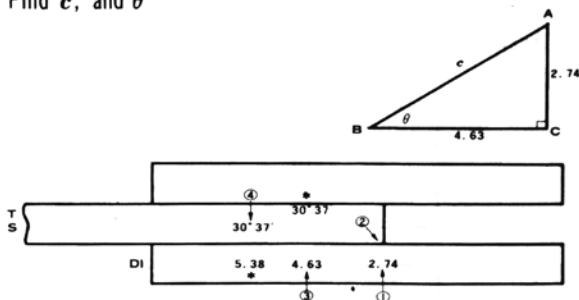
FUNDAMENTAL OPERATION (15) RIGHT TRIANGLES

The right triangle is solved by setting the slide as illustrated in the figure below.



This method is used to solve right triangles, vector calculations, complex numbers, etc.

Ex. 9.10 Find c , and θ

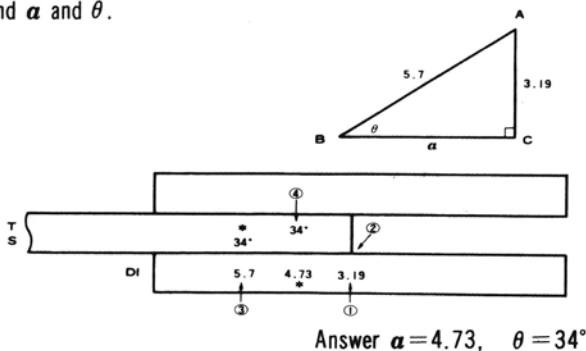


Answer $c = 5.38$, $\theta = 30^\circ 37'$

(Note) $\sqrt{2.74^2 + 4.63^2} = 5.38$ is also calculated using the method illustrated.

In this case θ is called "parameter".

Ex. 9.11 Find a and θ .

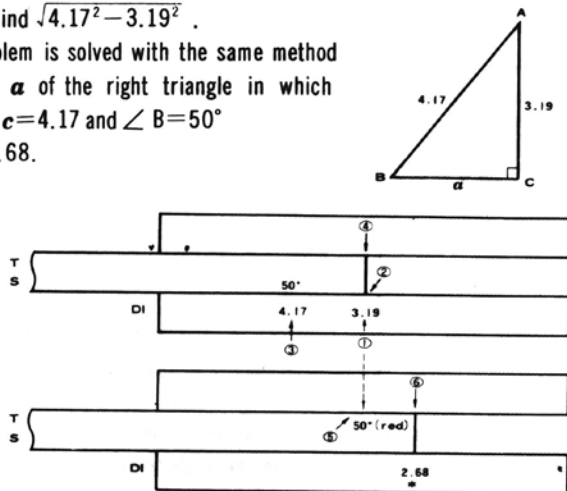


(Note) Calculating $\sqrt{5.7^2 - 3.19^2} = 4.73$ can be performed in the same manner as illustrated above.

Ex. 9.12 Find $\sqrt{4.17^2 - 3.19^2}$.

This problem is solved with the same method used to find a of the right triangle in which $b = 3.19$ and $c = 4.17$ and $\angle B = 50^\circ$

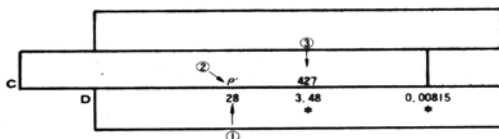
Answer 2.68.



$$\begin{aligned}
 1 \text{ radian} &= \frac{180^\circ}{\pi} = 57.29^\circ \dots\dots\dots r \\
 &= \frac{180 \times 60'}{\pi} = 3437.75' \dots\dots\dots \rho' \\
 &= \frac{180 \times 60 \times 60''}{\pi} = 206265'' \dots\dots\dots \rho''
 \end{aligned}$$

The gauge marks r , ρ' and ρ'' indicate the above value. Therefore, by dividing the angle (θ) on the D scale by the gauge mark, the angle (θ) is converted to its equivalents (θ radians). For the location of the decimal point you will use these values $\sin 1' = 0.0003$ and $\sin 1'' = 0.000005$.

Ex. 9.15 $\tan 28' = 0.00815$ $427 \times \sin 28' = 3.48$



CHAPTER 10. CIVIL ENGINEERING CALCULATION

§1. STADIA CALCULATIONS

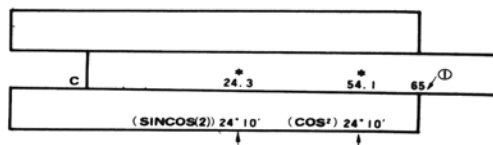
The SINCOS and $\cos^2$ scales are arranged on the lower part of the body on the back face of this slide rule. The SINCOS scale consists of two scales (1) and (2) and the angles are shown in black numbers. (The part with the red numbers on the right side of the (2) scale of the SINCOS scale is the $\cos^2$ scale.) When θ is set on the SINCOS scale, the value of $\sin \theta \cdot \cos \theta$ is read on the D scale. When θ is set on the $\cos^2$ scale, the value of $\cos^2 \theta$ is read on the D scale. When θ is set on the (1) SINCOS scale, the value of $\sin \theta \cdot \cos \theta$ on the D scale is in the range 0.01 ~ 0.1 and when θ is set on the (2) scale of SINCOS and $\cos^2$, $\sin \theta \cdot \cos \theta$ and $\cos^2 \theta$ on the D scale are in the range 0.1 ~ 1. This is shown by the marks .01 ~ .1, and .1 ~ 1 on the right end. These scales are used for stadia calculations in the following manner.

In stadia survey, the following formulas are necessary to find the horizontal distance " d " between the transit and the observation point, and undulation differential " h " from reading of the stadia " Ka " and an angle " θ ",

$$d = Ka \cdot \cos^2 \theta$$

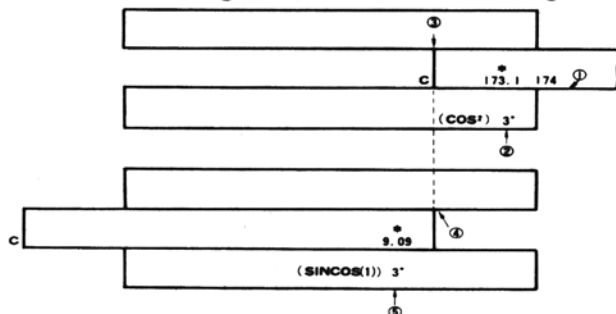
$$h = Ka \cdot \sin \theta \cdot \cos \theta$$

Ex. 10.1 Find the horizontal distance d and the undulation differential h , if the reading of the stadia is 65m and angle $24^\circ 10'$ are given.



Answer $d = 54.1\text{m}$, $h = 24.3\text{m}$

Ex. 10.2 Find the horizontal distance d and the undulation differential h , if the reading of the stadia is 174m and angle 3° are given.

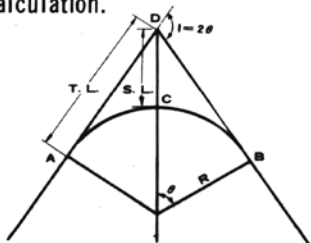


Answer $d = 173.1\text{m}$, $h = 9.09\text{m}$

In this example, resetting the index is necessary because the scale runs off.

§ 2. CURVE SETTING CALCULATION.

The CL, SL and TL scales on the upper part of the body on the back face of this slide rule, and the R scale on the slide are used for curve setting calculation.

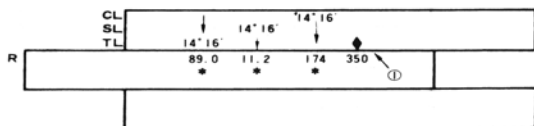


I ; the intersection angle,
 R ; the radius of the curve,
 $T.L.$; tangent length,
 $S.L.$; external secant,
 $C.L.$; the length of curve ABC

The CL scale indicates curve length, the SL scale external secant, the TL scale tangent length, and the R scale radius of a curve, respectively. The signs, such as $.1 \sim 1 \sim 10$, on the right end of each scale, indicate range of reading. When the slide rule is closed for example, $.01 \sim .1 \sim 1$ on the SL scale indicates that a number on the R scale opposite the SL scale is read at the range $.01 \sim .1 \sim 1$.

Ex. 10.3 Find C.L., S.L., T.L. if the intersection angle $I = 28^\circ 32'$ and the radius of curve $R = 350\text{m}$.

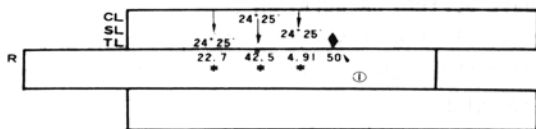
$$\theta = \frac{I}{2} = \frac{28^\circ 32'}{2} = 14^\circ 16'$$



Answer C.L. = 174m, S.L. = 11.2m, T.L. = 89.0m

Ex. 10.4 Find C.L., S.L., and T.L. if $I = 48^\circ 50'$, $R = 50\text{m}$.

$$\theta = \frac{I}{2} = \frac{48^\circ 50'}{2} = 24^\circ 25'$$

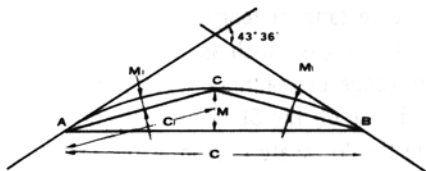


Answer C.L. = 42.5m, S.L. = 4.91m, T.L. = 22.7m

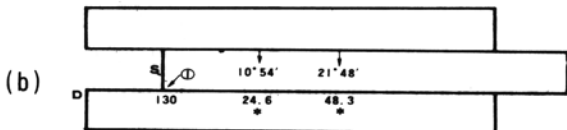
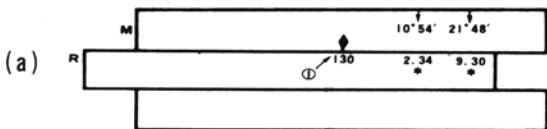
§ 3. SETTING THE MIDDLE ORDINATE.

The M, R, S and D scales are used for calculation of middle ordinate. The M scale can be conveniently used for calculation of $1 - \cos \theta$.

Ex. 10.5 Find M, M_1 and $\frac{1}{2}C$ and $\frac{1}{2}C_1$, if the intersection angle $I = 43^\circ 36'$ and the radius is $R = 130\text{m}$ are conditional.



$$\theta = \frac{I}{2} = \frac{43^{\circ}36'}{2} = 21^{\circ}48', \theta_1 = \frac{\theta}{2} = \frac{21^{\circ}48'}{2} = 10^{\circ}54'$$



Answer $M = 9.30m$, $M_1 = 2.34m$, $\frac{1}{2} C = 48.3$, $\frac{1}{2} C_1 = 24.6m$

When $M_2, \frac{1}{2} C_2, M_3, \frac{1}{2} M_3$ must be found continuously, first calculate as follows;

$$\theta_2 = \frac{\theta_1}{2} = \frac{10^{\circ}54'}{2} = 5^{\circ}27', \theta_3 = \frac{\theta_2}{2} = \frac{5^{\circ}27'}{2} = 2^{\circ}43'30''$$

The rest can then be found in the same operation as **a** and **b** in the above illustration. In this case, if the angle is smaller than 6° , the ST scale instead of the S scale should be used.

Ex. 10.6 Find middle ordinate M and M_1 , if intersection $I = 62^{\circ}28'$ and radius of the curve $R = 60m$.

$$\theta = \frac{62^{\circ}28'}{2} = 31^{\circ}14'$$

On this slide rule, the M scale covers angles up to 26° . Therefore, we perform the calculation using the formula $M = R(1 - \cos \theta)$.

(1) Find $\cos 31^{\circ}14' = 0.855$ using the S scale.

(2) Calculate $1 - 0.855 = 0.145$

(3) Find $R \times 0.145 = 60 \times 0.145$ and read the value of M .

However, for the value of M_1 , you will use the M scale as Ex. 10.5 since

$$\theta_1 = \frac{\theta}{2} = 15^{\circ}37'.$$

§ 4. MANNING'S EQUATION (HYDRAULICS)

Manning's equation is most often used to find the velocity of flow in a pipeline.

$$v = \frac{1}{n} R^{\frac{2}{3}} I^{\frac{1}{2}}, \quad R = \frac{A}{S}$$

v : velocity (m/sec)

n : Kutter's coefficient of roughness,

A : sectional area of the pipe (m^2)

S : Wetted perimeter of pipe (m)

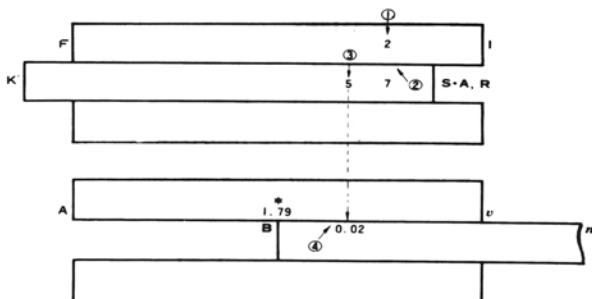
R : hydraulic radius

I : hydraulic gradient

The velocity of flow can be efficiently calculated by use of the F, A, B and K' scales on the front face. All the marks, such as I and v , on the right end of the scale indicate the magnitudes used in the above formula. For example, at the right of the B scale the marking $n (.01-1)$ is printed. This means the left end of the B scale should be read as .01 and the right end should be read as 1. Calculations which are performed according to the ranges indicated at the right will not result in off-scale positions and will eliminate the necessity of determining the place number of the answer.

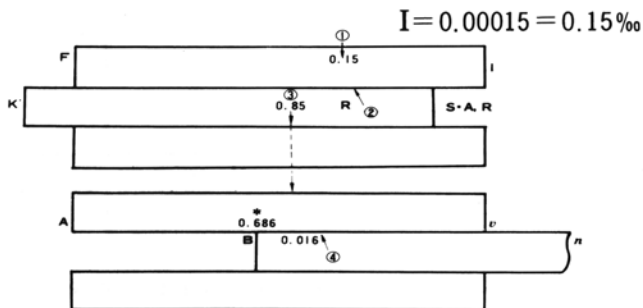
Ex. 10.7 Find the velocity of flow when $A = 5m^2$, $S = 7m$, $I = 2\%$ and $n = 0.02$. When A and S are given, the calculation is made as follows.

- (1) Set the hairline over I on the F scale,
- (2) move the slide to set S on the K' scale to the hairline,
- (3) move the hairline to set over A on the K' scale,
- (4) move the slide to bring n on the B scale to the hairline,
- (5) read the answer v on the A scale opposite the left index of the B scale.



Ex. 10.8 Find the velocity of flow when $R = 0.85\text{m}$, $I = 0.00015$ and $n = 0.016$. When $R (= \frac{A}{S})$ is given, the calculation can be performed in the following manner.

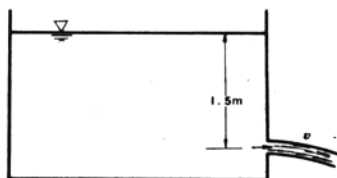
- (1) Set the hairline over I on the F scale.
- (2) Move the slide and set the gauge mark " R " of the K' scale to the hairline.
- (3) Move to set the hairline over R on the K' scale.
- (4) Move the slide and set n on the B scale to the hairline.
- (5) Read v on the A scale opposite the left index of the A scale.



(Note) The gauge mark " R " indicates the position of 100 on the K' scale, that is, it indicates I when it is read with the units $S \cdot A, R$.

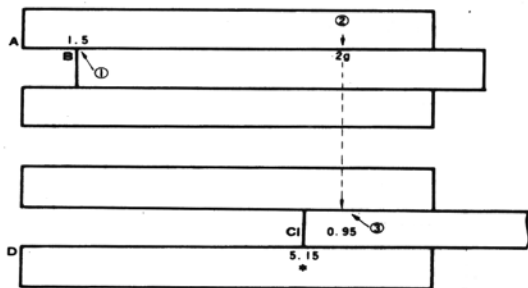
CHAPTER 11. OTHER APPLICATIONS

- §1. There is a small orifice in the side wall of a water tank. The velocity of flow v from the small orifice can be shown as $v = C_v \sqrt{2gh}$. Find the velocity of flow v in the illustration. The coefficient of velocity of flow $C_v = 0.95$ and $g = 9.8 \text{ m/sec}^2$.

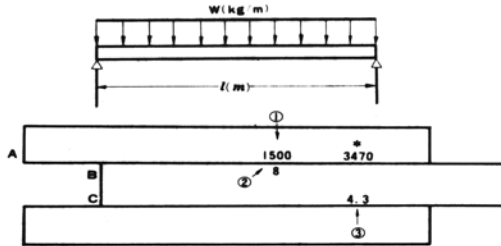


The gauge mark "2g" is at the position of 19.6 on the B scale. Using this simplifies the calculation.

$$v = 0.95 \sqrt{2g \times 1.5} = 5.15 \text{ m/sec}$$

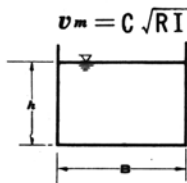


- §2. A uniformly distributed load is falling on the beam as illustrated. In this case the maximum curve moment M_{max} is $M_{max} = \frac{wl^2}{8}$. Find M_{max} when $l = 4.3 \text{ m}$ and $w = 1500 \text{ kg/m}$.



$$\text{Answer } M_{\max} = \frac{1500 \times 4.3^2}{8} = 3470 \text{ kg}\cdot\text{m}$$

§3. Chezy's formula is used to find the velocity of flow v_m of an open channel.



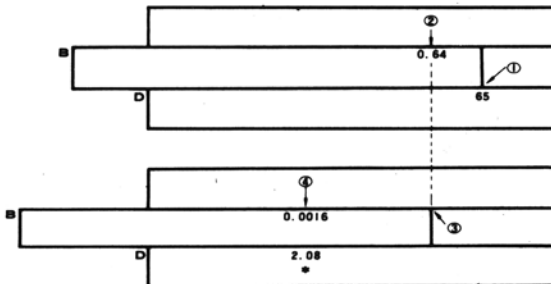
C: Coefficient of velocity of flow.

R: Hydraulic radius

I: Surface slope

Find v_m when $C=65$, $R=0.64\text{m}$ and $I=0.0016$

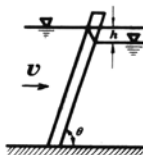
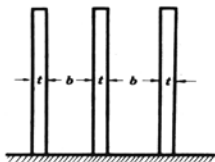
$$v_m = 65 \sqrt{0.64 \times 0.0016} = 2.08 \text{ m/sec}$$



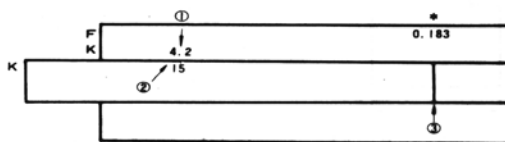
§4. Water head loss due to a screen can be found in the following manner .
$$h = \beta \left(\frac{t}{b} \right)^{\frac{4}{3}} \cdot \frac{v_1^2}{2g} \cdot \sin \theta$$

β : Loss coefficient of screen.

g : Acceleration potential of gravity.



This slide rule permits to calculate the part $\left(\frac{t}{b} \right)^{\frac{4}{3}}$ conveniently; for example, when $b=15$ and $t=4.2$, the calculation is performed as illustrated below.



Answer 0.183

CARE AND ADJUSTMENT OF THE SLIDE RULE

※WHEN THE SLIDE DOES NOT MOVE EASILY

Pull the slide out of the body and remove any dirt adhered to the sliding surfaces of the slide and the body with a toothbrush. Using a little of wax will also help.

Every Hemmi slide rule should come to you in proper adjusted condition. However, the inter-action of the slide and body, if necessary, can be adjusted to your own preference of tension.

First, loosen a screw at one end of the rule. Then, if you feel the slide fits tight, pull this end away from the slide, and if you feel the slide fits loose, push this end toward the slide and retighten the screw. Do the same at another end and repeat the same operation until the slide fits properly.

※WHEN THE INDICATOR GLASS BECOMES DIRTY

Place a narrow piece of paper between the indicator glass and the surface of the rule, press the indicator glass against the piece of paper, and work the indicator back and force several times until the dirt particles under the glass adhere to the piece of paper.

※HOW TO ADJUST THE HAIRLINE

The hairline should always be perpendicular to the scales. If it is not, loosen the four screws of the indicator frame and move the glass until perfect alignment is obtained and tighten the screws.

※HOW TO ADJUST THE SCALES

When the slide is moved until the D and D scales coincide, the DF and CF or A and B scales should be coincide. However, the adjustment of the rule may be lost if the rule is dropped or severely jarred. In this case, loosen the screws at both ends of the rule and move the upper body member right or left until the DF or A scale coincides with CF or B scale, and tighten the screws.

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