Relay

BAMBOO SLIDE RULES

INSTRUCTION
for
General Calculation

SAN-AI KEIKI CO., LTD.
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Advantages of "Relay" Bamboo Slide Rule

Bamboo, which is a special product of Japan, does not shrink or lengthen under any change of atmospheric temperature and humidity. Each part of the "Relay" Bamboo Slide Rule is composed of 2-5 pieces of well selected and seasoned bamboo.

The graduations of the "Relay" Bamboo Slide Rule are divided, line by line, by a special machine, so it is very accurate and distinct.

The Scales and Their Uses

The following is the brief description of the various scales of the "Relay" Bamboo Slide Rules.

1. C and D scales. These fundamental scales are exactly alike and are used for all operations; multiplication and division etc.

2. CF and DF scales. These are C and D scales "folded" at π ($\pi = 3.1416$), and are used with C and D scales in order to decrease the number of operations.

3. CI scale. This is an "inverted" C scale, and is used with C scale in reading directly the reciprocal of a number.

4. CIF scale. This is a CI scale "folded" at π, and is used with CF scale in the same relation as CI scale with C scale.

5. S scale. This scale gives the sines and cosines of angles.

6. T scale. This scale gives the tangents and cotangents of angles.

7. S&T scale. This scale gives the sines and tangents of small angles.

8. A and B scales. These scales consist of two half size of C or D scales placed end to end. These scales are used with C and D scales to give squares and square roots.

9. K scale. This scale consists of three one-third size of C

scale placed end to end, and is used in finding cubes and cube roots.

10. L scale. This scale is used with D scale in giving directly the mantissa of the common logarithm of a number.

11. LL scale. Some of our slide rules have so called log log scales, which are used in calculating expression such as x^y $(x>1)$. LL scales also give directly the value of the function e^x and are used in reading the natural logaithms of numbers.

Article No.		Scale Range
651, 107	LL_1	from $e^{0.1}=1.105$ to $e=2.718$
	LL_2	from $e=2.718$ to $e^{10}=22026$
	with some extension scales on both ends, used with C and D scales.	
100	LL	from $e^{0.1}=1.105$ to $e^{10}=22026$
	with some extension scales on both ends, used with A and B scales.	
150	LL_1	from $e^{0.01}=1.010$ to $e^{0.1}=1.105$
	LL_2	from $e^{0.1}=1.105$ to $e=2.718$
	LL_3	from $e=2.718$ to $e^{10}=22026$
	used with C and D scales.	

12. LL_0, LL_{00} and RLL scales. Some of our slide rules also have LL_0, LL_{00} and RLL scales, which are used with A and B scales in finding powers of numbers smaller than 1, x^y

($x<1$). These also give directly the values of the functions e^x for negative values of x.

Article No.		Scale Range
100	RLL	from $e^{-0.1}=0.905$ to $e^{-10}=0.0000454$
	with some extension scales on both ends.	
150	LL_0	from $e^{-0.001}=0.999$ to $e^{-0.1}=0.905$
	LL_{00}	from $e^{-0.1}=0.905$ to $e^{-10}=0.0000454$

Slide Rule Operations

In what follows, the left hand 1 of a scale is called its Left Index, the right hand 1 is called its Right Index.

1. Multiplication

Rule: a Locate one of the factors on D and set the right or left index of C on it.

b Opposite the other factor on C, read the product on D.

Example 1. $24 \times 3 = 72$

a Opposite 24 on D, set the left index of C.

b Opposite 3 on C, read answer 72 on D.

Example 2. $4.5 \times 3.2 = 14.4$

a Opposite 45 on D, set the right index of C.

b Opposite 32 on C, read answer 14.4 on D.

Note in this case that the reading would have been "Off Scale" if the left index had been used.

The decimal point may be fixed by making a rough mental calculation.

2. Continuous Multiplication

To multiply three factors, first multiply two of them, and then multiply the result by the third.

Example $1.5 \times 3.2 \times 8 = 38.4$

a Opposite 15 on D, set the left index of C.

b Opposite 32 on C, set the hair line.

c Opposite the hair line, set the right index of C.

d Opposite 8 on C, read answer 38.4 on D.

You need not read the intermediate answer $1.5 \times 3.2 = 4.8$. The decimal point can be determined by a rough mental calculation.

3. Division

Rule: a Locate the dividend on D, set the diviser on C.

b Opposite the index of C, read the quotient on D.

Example $58.5 \div 3 = 19.5$

a Opposite 58.5 on D, set 3 on C.

b Opposite the left index of C, read 19.5 on D.

As you see, this operation is exactly the inverse of multiplication.

4. Mixed Calculation of Multiplication and Division

Example $\dfrac{1.47 \times 30 \times 4}{3.5 \times 2} = 25.2$

a Opposite 1.47 on D, set 3.5 on C.

b Opposite 3 on C, set the hair line of runner.

c Opposite the hair line, set 2 on C.

d Opposite 4 on C, read 25.2 on D

5. The Folded Scale CF and DF

CF and DF scales are similar to C and D scales folded at π. As π is very near to $\sqrt{10}$, so 1 of CF and DF scales lie about in the middle and π on both ends of scale. These scales can often be used in calculation in order to avoid resetting when the answer runs off scale.

Example Convert 2 and 6 feet in metres.

As 292 feet=89 metres (see the "Table of Constant" on back face of slide rule.)

a Opposite 89 on D, set 292 on C.

b Opposite 2 on C, read 0.61 on D (2f=0.61m)

c Opposite 6 on CF, read 1.83 on DF (6f=1.83m)

As you see in above example, when the slide is in any position with a number x on the D scale appearing opposite a number y on the C scale, then this same number x appears also on the DF scale opposite y on the CF scale. If the reading is off scale on the C-D scale it may be found on the CF-DF scale.

Moreover we can use the CF and DF scales in problems requiring multiplication by π ($\pi=3.142$ approximately). Opposite any number on the D scale, read π times of this

number on the DF scale. Thus if we take any number on the D scale as diameter of a circle, its circumference can be found on the DF scale.

6. Squares and Square Roots

Opposite any number on the C scale, read its square on the B scale.

Example Opposite 3.5 on C, read $3.5^2=12.35$ on B.

Conversely opposite any number on the B scale, read its square root on the C scale.

Example Opposite 484 on B (left), read $\sqrt{484}=22$ on C.

Example Opposite 0.64 on B (right), read $\sqrt{0.64}=0.8$ on C.

Use the left or right half of the B scale as shown in the following table.

A given number	left half of B	right half of B
	1 ··· 10	10 ··· 100
	100 ··· 1000	1000 ··· 10000
	⋮	⋮
	⋮	1 ··· 0.1
	0.1 ··· 0.01	0.01 ··· 0.001
	0.001 ··· 0.0001	0.0001 ··· 0.00001

7. Cubes and Cube Roots

Opposite any number on the D scale, read its cube on the K scale. Thus Opposite 3.2 on D, read $3.2^3=32.8$ on K.

The decimal point may be fixed by making a rough mental calculation.

Conversely, opposite a number on the K scale, read its cube on the D scale.

Example Opposite 5360 on K (left), read $\sqrt[3]{5360}=17.5$ on D.

Example Opposite 28.6 on K (middle), read $\sqrt[3]{28.6}=3.06$ on D.

Example Opposite 0.186 on K (right), read $\sqrt[3]{0.186}=0.571$ on D.

Use left, middle or right third of K scale as shown in the following table.

a given number	left third of K	middle third of K	right third of K
	1···10	10···100	100···1000
	1000···10000	10000···100000	100000···1000000
	⋮	⋮	⋮
	0.01···0.001	0.1···0.01	1···0.1
	0.00001···0.000001	0.0001···0.00001	0.001···0.0001

8. Reciprocal

Opposite any number on the C scale, read its reciprocal on the CI scale. The number on the CI scale is given by the red figures.

Example Opposite 2.5 on C, read $\frac{1}{2.5}=0.4$ on CI.

Example Opposite 125 on C, read $\frac{1}{125}=0.008$ on CI.

9. Another Fundamental Calculation

a. $a^2b=x$ $1.5^2\times 3.14=7.07$

a Opposite a on D, set left index of C.

b Opposite b on B, read x on A.

b. $a^2b^2=x$ $72^2\times 0.45^2=1050$

a Opposite a on D, set right index of C.

b Opposite b on C, read x on A.

c. $\frac{a^2}{b}=x$ $\frac{11^2}{4.9}=24.7$

a Opposite a on D, set b on B.

b Opposite index of C, read x on A.

d. $\frac{a^2b}{c}=x$ $\frac{8.05^2\times 0.34}{51.5}=0.428$

a Opposite a on D, set c on B.

b Opposite b on B, read x on A.

e. $\sqrt{ab}=x$ $\sqrt{1.83\times 0.26}=0.69$

a Opposite a on A, set index of B.

b Opposite b on B, read x on D.

f. $\frac{a}{\sqrt{b}}=x$ $\frac{79.3}{\sqrt{2.35}}=51.7$

a Opposite a on D, set b on B.

b Opposite index of C, read x on D.

g. $\frac{a\sqrt{b}}{c}=x$ $\frac{31.93\times\sqrt{147}}{3.2}=120.9$

a Opposite a on D, set c on C.

b Opposite b on B, read x on D.

h. $ab^3=x$ $0.65\times2.3^3=7.91$

a Opposite a on K, set index of C.

b Opposite b on C, read x on K.

i. $\frac{ab^3}{c^3}=x$ $\frac{1.95\times6.08^3}{3.9^3}=7.39$

a Opposite a on K, set c on C.

b Opposite b on C, read x on K.

j. $\sqrt{a^3b^3}=x$ $\sqrt{9.42^3\times4.12^3}=242$

a Opposite a on A, set index of B.

b Opposite b on B, read x on K.

As a=9.42, take a on left half of B, and as b=4.12 take b on left half of B.

10. The Sine of an Angle

To get the sine of an angle a, we use

S and C or D scale for No. 602, 115, 105, 100, 150.

S and B or A scale for No. 403, 505, 107, 450, 550, 650, 651, 652.

Opposite the mark at the right end of the back of the rule, set a on S.

Opposite the index of D, read sin a on C.

Example sin 22°

Opposite the mark (on the back face), set 22 on S.

Opposite index of D, read sin 22° =0.375 on C.

If an angle is between 34′ and 5°45′, use S&T scale. In this range the sine of an angle is between 0.01 and 0.1.

11. The Cosine of an Angle

We find the cosine of an angle a by reading the sine of its compliment 90—a, or

$$\cos 32° = \sin(90° - 32°) = \sin 58° = 0.848$$

12. The Tangent of an Angle

To get the tangent of an angle a, set a on T on the back face of the slide to the mark at the back right end of the rule, and read tan a on C against index of D.

Example tan 33°

Opposite the mark (on the back face), set 33 on T.

Opposite the index of D, read tan 33° = 0.65 on C.

13. The Sine and Tangent of an Angle smaller than 5°44′

To obtain the value of sine and tangent of an angle between 0°34′ and 5°44′, the S&T scale is used. Note that the value of sine and tangent of these small angles are nearly alike.

Example sin 1°30′ ($\fallingdotseq$tan 1°30′)

Set the hair line to 1°30′ on S&T, read 0.00262 on D.

14. Function of Angles Less than 0°34′

The values of angles smaller than 0°34′ can be obtained readily by using the relation.

sin a=tan a =a (in radian) approximately.

0.1 =0.002 radians

0.1′ =0.0003 radians

0.1″=0.000005 radians

Example sin 4′=4×0.0003=0.0012

15. Other Trigonometrical Functions

To get cotangent, secant and cosecant of an angle, we use the following formula.

$$\cot a = \frac{1}{\tan a}$$

$$\sec a = \frac{1}{\cos a}$$

$$\operatorname{cosec} a = \frac{1}{\sin a}$$

Thus, first take the tangent, cosine and sine of a then get their reciprocals.

16. Logarithms

Slide rule gives only the mantissa or decimal part of the common logarithms of a number, and the characteristic or the integral part can be determined by inspection. We use in this calculation L and C (D) scale.

L scale is on front face of rule for No. 602, 105 etc. and on back face of slide for No. 403, 505 etc.

In former case, we can directly read the mantissa of a number on L scale, but in later case, we operate as follows

Example log 38.7=1.588

a Opposite 38.7 on D, set index of C.

b Opposite the mark line of the back face, read 588 on L.

c Add characteristic 1, then the answer is 1.588.

17. The LL Scales

As mentioned previously, some of our slide rules have LL scales, which give the value x^y, and natural logarithms of numbers. We add some brief descriptions on LL_{1-2-3} scales.

a. e^x $(0.01<x<10)$

These scales give the value e^x for values of x from 0.01 to 10.

Opposite x on D, read e^x on LL.

LL_1 if x is between 0.01 and 0.1;

LL_2 if x is between 0.1 and 1;

LL_3 if x is between 1 and 10;

Example Opposite 3 on D, read $e^3=20.1$ on LL_3;

$e^{0.3}=1.350$ on LL_2;

$e^{0.03}=1.0304$ on LL_1,

b. Natural Logarithms

Logarithms to the base e (e=2.71828) are called natural logarithms. We denote the natural logarithms of a number N by the symbol InN. We can read from LL scales natural logarithms of a number between 1.010 $(=e^{0.01})$ and 22026 $(=e^{10})$.

Opposite 8.4 on LL_3, read In8.4=2.13 on D;

Opposite 1.45 on LL_2, read $\ln 1.45 = 0.372$ on D;
Opposite 1.04 on LL_1, read $\ln 1.04 = 0.0392$ on D;

18. The LL_0 and LL_{00} (or RLL) Scales

These scales operate with A or B in the same way that the LL_{1-2-3} scales combination operate with C and D.

a. e^{-x} $(0.001 < x < 10)$

If x is 0.001–0.01, use left half of A, read e^{-x} on LL_0;
0.01–0.1 use right half of A, read e^{-x} on LL_0;
0.1–1, use left half of A, read e^{-x} on LL_{00};
1–10, use right half of A, read e^{-x} on LL_{00};

Example 3 on left half of A, read $e^{-0.003} = 0.9970$ on LL_0;
3 on right half of A, read $e^{-0.03} = 0.9704$ on LL_0;
3 on left half of A, read $e^{-0.3} = 0.741$ on LL_{00};
3 on right half of A, read $e^{-3} = 0.0497$ on LL_{00};

b. Natural Logarithms

Using LL_0, LL_{00} scales, we can read uatural logarithms of a number between 0.999 and 0.00005.

Example

Opposite 0.65 on LL_{00}, read $\ln 0.65 = -0.431$ on A;
Opposite 0.94 on LL_0, read $\ln 0.94 = -0.0619$ on A;

19. Calculation of x^y

Of couse, we can calculate the value of x^y by multiplying the common logarithms of x by y, and then reading the

antilogarithm. More convenient method is as follows,

Example 1. $1.67^{1.45}=2.102$

a Opposite 1.67 on LL_2, set index of C.

b Opposite 1.45 on C, read 2.102 on LL_2

Example 2. $2.18^{4.63}=37.1$

a Opposite 2.18 on LL_2, set index of C.

b Opposite 4.63 on C, read 37.1 on LL_3.

Example 3. $0.64^{1.8}=0.448$

a Opposite 0.64 on LL_{00}, set left index of B.

b Opposite 1.8 on left half of B, read 0.448 on LL_{00}.

Details of "Relay" Bamboo Slide Rules

Article No.	Length		Scale
403—I(MI)	4″		A.B.CI.C.D/S.L.T.
505—I	5″		A.B.CI.C.D.K/S.L.T.
515—I	5″		A.B.CI.C.D.K/T_2.T_1.L.S.
512—I	5″		DF.CF.CI.C.D.A/S.L.T.
513—I	5″		DF.CF.CI.C.D.A/T_2.T_1.L.S.
602—I	6″		K.A.B.CI.C.D.L/S.S&T.T.
605—I	6″		LL_1.A.B.CI.C.D.LL_2. Volt Dynamo-Motor./S.L.T.
80—I	8″		A.B.CI.C.D.
82—I	8″		A.B.CI.C.D.K/S.L.T.
83—I	8″		K.DF.CF.CI.C.D.A/S.L.T.
84—I	8″		K.DF.CF.CI.C.D.A/S.L.T.
102—I	10″		A.B.CI.C.D.K/S.L.T.
103—I	10″		K.DF.CF.CI.C.D.A/S.L.T.
105—I	10″		K.A.B.CI.C.D.L/S.S&T.T.
112—I	10″		A.DF.CF.CI.C.D.K/S.L.T.
113—I	10″		A.DF.CF.CIF.CI.C.D.K/T_1.T_2.L.S.
114—I	10″		K.DF.CF.CI.C.D.A/T_2.T_1.L.S.
115—I	10″		K.A.B.CI.C.D.L/T_1.T_2.ST.S.
104—I	10″		L.LL.D_1.M_2.M_1.C.D.K.A/S.S&T.T.
107—I	10″		Dynamo-Motor. E.V.A.B.K.CI.C. D.S.T./LL_3LL_2.LL_1.L.
120—I	10″	Darmstadt	L.K.A.B.CI.C.D.P.S.T/L_1.L_2.L_3.
450—I	4″	Duplex	DF.CF.CI.C.D/A.S.L.T.D.
550—I	5″	Duplex	DF.CF.CI.C.D.L/A.B.S.T.C.D.K.
650—I	6″	Duplex	DF.CF.CIF.C.D/K.A.B.S.T.CI.D.L.
651—I	6″	Duplex	LL_1.DF.CF.CI.C.D.LL_2/ K.A.B.S.T Dynamo-Motor. Volt.
652—I	6″	Duplex	K.DF.CF.CIF.CI.C.D.L/ LL.A.B.S.T.C.D.LL_0.
150—I	10″	Duplex	L.LL_1.DF.CF.CIF.CI.C.D.LL_3.LL_2./ LL_0.LL_{00}.A.B.K.CI.C.D.S.ST.T.
151—I	10″	Duplex	LL_T.$LL_{\bar{2}}$.$LL_{\bar{3}}$.DF.CF.CIF.CI.C.D.LL_3.LL_2. LL_1./$LL_{\bar{0}}$.L.K.A.B.S.ST.T.C.D.DI.P.LL_0.
152—I	10″	Duplex	DF.CF.CIF.CI.C.D.L./ K.A.B.S.ST.T.C.D.DI.
153—I	10″	Duplex	L.LL_1.DF.CF.CIF.CI.C.D.LL_3.LL_2/ K.A.B.S.ST.T.C.D.DI.
157—I	10″	Duplex	Sr.Sø.P′.P.Q.CF.CI.C.D.DF.LL_1′.LL_2.LL_3/ Sh_2.Sh_1.A.B.K.Th.C.D.Tr_1.Tr_2.db.
158—I	10″	Duplex	Sh_2.Sh_1.Th.A.BI.S.T.CI.C.D.LL_3.LL_2.LL_1/ X_2.X_1.P_2.P_1.Q.Y.L.$\underline{X}$.I.I_3.$\underline{0_1}$.$\underline{0_2}$.$\underline{Y}$.

"Relay" plastic Slide Rules

42—I	4″	A.B.CI.C.D/S.L.T.
53—I	5″	DF.CF.CI.C.D.A/S.L.T.
55—I	5″	A.B.CI.C.D.K/S.L.T.

Remarks I ..... with instruction book
M ..... with Magnifier

Rules with mangnifier need no carboards in principle.