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DECIMAL TRIG TYPE LOG LOG · 1737

SELF TEACHING INSTRUCTION MANUAL

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FOR THE USE OF YOUR SLIDE RULE

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1. GENERAL DESCRIPTION OF SCALES

The following is a brief description of the scales.

(a) **C and D**

These are exactly alike and are the fundamental scales of the slide rule. They are used for general fundamental calculations.

(b) **DF and CF**

These are the same as the D and C scales, except that they are "folded" at π. Therefore, any number on the D scale is automatically multiplied by π on the DF scale. In order to avoid resetting when the answer runs off the scale, they are used with the C and D scales.

(c) **CI**

This is an inverted C scale; it is used with the C scale in reading directly the reciprocal of a number. It permits multiplication of three factors with just one setting of the slide.

(d) **DI**

This is an inverted D scale and is used just the same as the CI scale.

(e) **CIF**

This is an inverted CF scale and is used with the DF scale in the same relation as the CI scale to the D scale.

(f) **A and B**

These are exactly alike and are used with the C and D scales to find the square and square root.

(g) **K**

This is used in finding the cube and cube root.

(h) **S**

This scale gives the sine and cosine of an angle.

(i) **T or T_1**

This scale gives the tangent of an angle.

(j) **T_2**

This scale gives the tangent of an angle greater than 45°.

(k) **L**

This scale is used with the D scale in finding directly the mantissa of the common logarithms of a number.

(l) **LL_1, LL_2 and LL_3**

These are used to find the values of the type form of a^n, e^x, and give the natural logarithms of a number.

(m) **$LL_{\overline{1}}$, $LL_{\overline{2}}$ and $LL_{\overline{3}}$**

These are used to find the values of the type form of a^{-n}, e^{-x} and give the natural logarithms of a number.

2. MULTIPLICATION AND DIVISION

(1) How to Use C and D Scales

In the following explanation the left hand 1 of the C or D scale is called its Left Index, the right hand 1 is called its Right Index.

(Multiplication)

The process of multiplication may be performed by using the C and D scales

To multiply a by b,

opposite a on D, set left or right index of C,
move hairline to b on C,
under hairline read the product on D.

Example 1. $2.4\times3=7.2$

Opposite 24 on D, set left index of C,
move hairline to 3 on C,
under hairline read answer as 7.2 on D.

Example 2. $262\times33.2=8700$

Opposite 262 on D, set left index of C,
move hairline to 332 on C,
under hairline find 870 on D,
read answer as 8700.

The position of the decimal point is made by rough mental calculation as follows:

$$262\times33.2\fallingdotseq300\times30=9000$$

Comparing 9000 with 87 which was obtained by the slide rule, it is apparent the answer is 8700.

Example 3. $4.5\times3.2=14.4$

Opposite 45 on D, set right index of C,
move hairline to 32 on C,
under hairline find 1 44 on D,

read answer as 14.4.

Note in above case that the reading would have been off scale, if the left index had been used.

(Division)

The process of division is performed by using the C and D scales

To divide a by b,

move hairline to a on D,

set b on C under hairline,

opposite left or right index of C read the quotient on D.

Example 4. $32 \div 8 = 4$

Move hairline to 32 on D,

set 8 on C under hairline,

opposite right index of C read answer as 4 on D.

(Combined Multiplication and Division)

To calculate the type form of $\frac{a \times c}{b}$, first divide a by b, and then multiply the quotient by c.

Example 5. $\frac{1.57 \times 32}{44} = 1.142$

Move hairline to 157 on D,

set 44 on C under hairline,

move hairline to 32 on C,

under hairline read answer as 1.142 on D.

(2) **How to Use CI Scale**

(Reciprocal)

The reciprocal of a number is 1 divided by the number. Thus, the reciprocal of 2.5 is $\frac{1}{2.5}$ or 0.4. Opposite any number on the C scale, read its reciprocal on the CI scale. The number on the CI scale is given in red figures.

Example 6. Opposite 2.5 on C, read $\frac{1}{2.5} = 0.4$ on CI.

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

(Multiplication)

The process of multiplication also may be performed by using the CI and D scales. By using the CI scale, computations can be made quickly.

To multiply a by b,

move hairline to a on D,

set b on CI under hairline,

opposite left or right index of C read the product on D.

Example 7. $2.3 \times 3.4 = 7.82$

Move hairline to 23 on D,

set 34 on CI under hairline,

opposite right index of C read answer as 7.82 on D.

Example 8. $4.77 \times 0.613 = 2.92$

Move hairline to 477 on D,

set 613 on CI under hairline,

opposite left index of C read answer as 2.92 on D.

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

Example 9. $1.5 \times 3.2 \times 8 = 38.4$

Move hairline to 15 on D,

set 32 on CI under hairline,

move hairline to 8 on C,

under hairline find 384 on D,

read answer as 38.4.

(Division)

The process of division also may be performed by

using the CI and D scales.

To divide a by b,
opposite a on D, set left or right index of C,
move hairline to b on CI,
under hairline read the quotient on D.

Example 10. $1.2 \div 4 = 0.3$
Opposite 12 on D, set left index of C,
move hairline to 4 on CI,
under hairline find 3 on D,
read answer as 0.3.

Example 11. $2.42 \div 2.03 = 1.192$
Opposite 242 on D, set right index of C,
move hairline to 203 on CI,
under hairline read answer as 1.192 on D.

Note in above example that the reading would have been off scale, if the left index had been used.

To divide three factors, first divide two of them, and then divide the answer by third.

Example 12. $15.7 \div 3.2 \div 4.4 = 1.115$
Move hairline to 157 on D.
set 32 on C under hairline,
move hairline to 44 on CI,
under hairline read answer as 1.115 on D.

(Combined Multiplication and Division)

The calculation of the type form of $\frac{a \times b}{c}$ follows out the procedure of multiplication and division.

Example 13. $\frac{8 \times 2}{5} = 3.2$
Move hairline to 8 on D,
set 2 on CI under hairline.

move hairline to 5 on CI,
under hairline read answer as 3.2 on D.

(3) How to Use DF and CF Scales

The DF and CF scales are similar to the D and C scales folded at π. As π is very near $\sqrt{10}$, so 1 of the DF and CF scales lies about in the middle and π on both ends of a scale. These scales often can be used in calculations in order to avoid resetting when the answer runs off the scale. When the slide is in any position with the number x on the D scale appearing opposite the 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. Thus, the DF and CF are extensions of scales D and C.

Moreover scales DF and CF can be used in problems requiring multiplication by π. Opposite any number on the D scale, read π times this number on the DF scale. Thus, by taking any number on the D scales as the diameter of circle, its circumference can be found on the DF scale.

These folded scales may be used to perform multiplication and division just as the C and D scales are used.

(Multiplication)

Example 14. $2.5 \times 5 = 12.5$
Opposite 25 on D, set left index of C,
(or opposite 25 on DF, set middle index of CF,)
move hairline to 5 on CF,
under hairline find 125 on DF,
read answer as 12.5.

As in above example, when the reading is off scale on the D scale, it may be found on the DF scale.

Example 15. $2.5\times2.4\times1.2=7.20$

Move hairline to 25 on D,
set 24 on CI under hairline,
move hairline to 12 on CF,
under hairline read answer as 7.20 on DF.

Example 16. $2\times7\times8=112$

Move hairline to 2 on D,
set 7 on CI under hairline,
move hairline to 8 on CF,
under hairline find 112 on DF,
read answer as 112.

(Division)

Example 17. $9\div6=1.5$

Move hairline to 9 on DF,
set 6 on CF under hairline,
opposite left index of C read answer as 1.5 on D.
(or opposite middle index of CF read answer as 1.5 on DF.)

Example 18. $9\div1.5\div4=1.5$

Move hairline to 9 on DF,
set 15 on CF under hairline,
move hairline to 4 on CI,
under hairline read answer as 1.5 on D.

(Combined Multiplication and Division)

Example 19. $11.2\div8.4\times2.7=3.6$

Move hairline to 112 on DF,
set 84 on CF under hairline,
move hairline to 27 on C,
under hairline read answer as 3.6.

Example 20. $\dfrac{3.2\times1.2\times5.8}{8.2\times9.5}=0.286$

Move hairline to 32 on D,
set 82 on C under hairline,
move hairline to 12 on CF,
set 95 on CF under hairline,
move hairline to 58 on C,
under hairline find 286 on D,
read answer as 0.286.

(Computation involving π)

By using the DF scale which is folded to begin and end with π, if the diameter of a circle d is set on the D scale, the circumference πd is given on the DF scale, opposite d on the D scale.

Example 21. (A) Find the circumference of a circle with a diameter of 5 in. (B) Find the diameter of a circle with a circumference of 46.8 in. Answer (A) 15.7 in. (B) 14.9 in.

(A) Move hairline to 5 on D,
under hairline find 1571 on DF,
read answer as 15.71 in.

(B) Move hairline to 468 on DF,
under hairline find 149 on D,
read answer as 14.9 in.

Example 22. Find the value of 3π. Answer 9.42

Move hairline to 3 on D,
under hairline read answer as 9.42 on DF.

Example 23. Find the value of $\dfrac{7}{\pi}$. Answer 2.23

Move hairline to 7 on DF,
under hairline read answer as 2.23 on D.

(4) How to Use CIF Scale

The CIF scale is an inverted CF scale. It may be used to perform multiplication and division just as the CI scale is used. Thus, by the use of six scales of the C, D, CI, CF, DF and this CIF, the fundamental calculations are performed very quickly and efficiently, without resetting the scale or running off the scale.

(Multiplication)

Example 24. $3.1\times1.6\times1.5\times8.8=65.5$

Move hairline to 31 on D,
set 16 on CI under hairline,
move hairline to 15 on CF,
set 88 on CIF under hairline,
opposite right index of C find 655 on D,
read answer as 65.5.

Example 25. $9\times8\times3\times7=1512$

Move hairline to 9 on DF,
set 8 on CIF under hairline,
move hairline to 3 on C,
set 7 on CI under hairline,
opposite left index of C find 1512 on D,
read answer as 1512.

(Division)

Example 26. $27\div5\div7.5=0.72$

Move hairline to 27 on D,
set 5 on C under hairline,
move hairline to 75 on CIF,
under hairline find 72 on DF,
read answer as 0.72.

(Combined Multiplication and Division)

Example 27. $3.8\times6.5\div2\times1.96\div1.45=16.7$

Move hairline to 38 on D,
set 65 on CI under hairline,
move hairline to 2 on CIF,
set 196 on CIF under hairline,
move hairline to 145 on CIF,
under hairline find 167 on DF,
read answer as 16.7

Example 28. $\dfrac{236000\times0.0065\times188\times715}{0.00032\times7800000}=82600$

Move hairline to 236 on D,
set 32 on C under hairline,
move hairline to 65 on C,
set 78 on C under hairline,
move hairline to 188 on CF,
set 715 on CIF under hairline,
opposite right index of C find 826 on D,
read answer as 82600.

The Position of the decimal point is made by rough mental calculation as follows:—

$$\frac{236000\times0.0065\times188\times715}{0.00032\times7800000}$$

$$=\frac{2.36\times6.5\times1.88\times7.15}{3.2\times78}\times\frac{10^{5-3+2+2}}{10^{-4+6}}$$

$$\fallingdotseq\frac{2\times7\times2\times7}{3\times8}\times\frac{10^{6}}{10^{2}}=\frac{\overset{1}{\cancel{2}}\times7\times\overset{1}{\cancel{2}}\times7}{3\times\underset{4}{\cancel{8}}}\times10^{6-2}$$

$$\fallingdotseq\frac{7\times7}{6}\times10^{4}\fallingdotseq\frac{50}{6}\times10^{4}\fallingdotseq8\times10^{4}=80000$$

Comparing 80000 with 826 which is obtained by the slide rule, the answer clearly is 82600.

3. PROBLEMS OF PROPORTION

Proportion is a special case of multiplication and division. Generally, when the slide scale is set at one point on the stock scale, there exists certain ratio relations between the scales on the slide and stock. So, the answer is given by moving of the hairline only.

There are two kinds of proportional problems, one is proportion and another inverse proportion.

(1) Proportion

The problems of proportion are widely applied to conversion, indexes, proportional division, percentage, etc.

Proportional calculation is performed by referring the C and D or CF and DF Scales to each other.

Example 29 Fill the following blanks, given 1kt=1.852 km/h.

kt	27	3.24	44
km/h	50*	6.0*	81.5*

*.....answer shown

Opposite 1852 on D, set left index of C,
move hairline to 27 on C,
under hairline find 5 on D,
read answer as 50.
Move hairline to 324 on C,
under hairline find 6 on D,
read answer as 6.0
Move hairline to 44 on C,
under hairline find 815 on C,
read answer as 81.5.

Example 30. Find % in the following table.

	Amount	%	
A	$2,410	14.6	*
B	$2,640	16.0	*
C	$3,400	20.6	*
D	$8,050	48.8	*
Total	$16,500	100.0	*

*.....shown answer

Opposite left index of D, set 165 on C,
move hairline to 241 on C,
under hairline find 146 on D,
read answer as 14.6.
Move hairline to 264 on C,
under hairline find 160 on D,
read answer as 16.0.
Move hairline to 34 on C,
under hairline find 206 on D,
read answer as 20.6.
Move hairline to 805 on C,
under hairline find 488 on D,
read answer as 48.8.

Example 31. $1.43 : 3.39 = 8.65 : x$ $x=20.5$

Move hairline to 339 on D,
set 143 on C under hairline,
move hairline to 865 on CF,
under hairline find 205 on DF
read answer as $x=20.5$.

(2) Inverse Proportion

Inverse proportion is calculated by referring the D and CI, or DF and CIF Scales to each other.

Example 32. A job requires 12 days for completion 45 with workmen. How many days will it take to complete it with 30 workmen? Answer 18 days

Move hairline to 12 on D,
set 45 on CI under hairline,
move hairline to 30 on CI,
under hairline find 18 on D,
read answer as 18.

Example 33. A pulley with 7″ diameter revolves 360 times per minute. How many revolutons per minute are there when diameter of pulley is 9″ Answer: 280 rpm

Move hairline to 36 on D,
set 7 on CI under hairline,
move hairline to 9 on CI,
under hairline find 28 on D,
read answer as 280.

4. SQUARE AND SQUARE ROOT

(1) Square Root

Opposite any number on the D scale, read its square on the A scale. Similarly, opposite any number on the C scale, read its square on the B scale.

Example 34. $2^2=4$, $5.63^2=31.7$

Move hairline to 2 on D,
under hairline read answer as 4 on A.
Move hairline to 563 on D,
under hairline read answer as 31.7 on A.

(2) Square Root

To find the square root of a number between 1 and 10, use scale A left. To find the square root of a number between 10 and 100, use scale A right. Or a given number is divided into several groups of two digits per group, counting from decimal point to the right or left. If the first group consists of only one figure, a given number is set on the scale A left. If it consists of two figures, a given number is set on the scale A right. Place the decimal point of the answer, taking one digit per group.

Example 35. $\sqrt{6.56}=2.56$, $\sqrt{6'56'00}=256$,
$\sqrt{0.00'06'56}=0.0256$

Move hairline to 656 on A left,
under hairline find 2.56 on D,

Example 36. $\sqrt{65.6}=8.1$, $\sqrt{65\ 60}=81$,
$\sqrt{0.00'00'65'6}=0.0081$

Move hairline to 656 on A right,
under hairline find 8.1 on D.

(3) Multiplication and Division including Square

Example 37. $2\times4^2=32$

Move hairline to 2 on A left,
set 4 on CI (back face) under hairline,
opposite right index of C read answer as 32 on A right.

Example 38. $1.3^2\times6.5^2=71.4$

Move hairline to 13 on D,
set 65 on CI (back face) under hairline,
opposite right index of C read answer as 71.4 on A right.

Example 39. $30\div5^2=1.2$

Move hairline to 30 on A right

set 5 on C under hairline,
opposite left index of C read answer as 1.2 on A left.

Example 40. $25^2 \div 50 = 12.5$

Move hairline to 25 on D,
set 50 on B right under hairline,
opposite right index of C read answer as 12.5 on A right.

Example 41. $2.4^2 \div 3.82^2 = 0.395$

Move hairline to 24 on D,
set 382 on C under hairline,
opposite right index of C find 395 on A right,
read answer as 0.395.

(4) Multiplication and Division including Square Root

Example 42. $\sqrt{20} \times 2 = 8.95$

Move hairline to 20 on A right,
set 2 on CI (back face) under hairline,
opposite right index of C read answer as 8.95 on D.

Example 43. $\sqrt{120 \times 36} = 65.7$

Opposite 120 on A left, set left index of C,
move hairline to 36 on B right,
under hairline find 657 on D,
read answer as 65.7.

Example 44. $\sqrt{36} \div 0.5 = 12$

Move hairline to 36 on A right,
set 5 on C under hairline,
opposite left index of C find 12 on D,
read answer as 12.

Example 45. $6 \div \sqrt{16} = 1.5$

Move hairline to 6 on D,
set 16 on B right under hairline,

opposite left index of C read answer as 1.5 on D.

Example 46. $\sqrt{2880 \div 8.35} = 18.57$

Move hairline to 288 on A right,
set 835 on B left under hairline,
opposite left index of C find 1857 on D,
read answer as 18.57.

(5) How to Use Gauge Mark "c"

area of circle $A = \frac{\pi}{4} d^2$ d=diameter of circle

$$= \left(\sqrt{\frac{\pi}{4}} \cdot d\right)^2 = \left(d \Big/ \sqrt{\frac{4}{\pi}}\right)^2$$

$\sqrt{\frac{4}{\pi}}$ corresponds to the value of "c". These gauge marks are graduated on the C and D scales, which are used for calculation of the area of a circle.

Example 47. Find the area of a circle with its diameter of 1.5cm. Answer 1.77cm²

Move hairline to 15 on D,
set c on C under hairline,
opposite left index of B read answer as 1.77 on A left.

Example 48. Find the volume of a cylinder with 1.2m in diameter and 5m in length. Answer 5.66m³

Move hairline to 12 on D,
set c on C under hairline,
move hairline to 5 on B left,
under hairline read answer as 5.66 on A left.

5. CUBE, CUBE ROOT, $\frac{3}{2}$ POWER AND $\frac{2}{3}$ POWER

(1) Cube

Opposite any number on the D scale, read its cube on

the K scale

Example 49. $2^3=8$, $3^3=27$, $7^3=343$

Move hairline to 2 on D,
under hairline read answer as 8 on K.
Move hairline to 3 on D,
under hairline read answer as 27 on K.
Move hairline to 7 on D,
under hairline read answer as 343 on K.

(2) Cube Root

To find the cube root of a number between 1 and 10, use scale K left. To find the cube root of a number between 10 and 100, use scale K middle. To find the cube root of a number between 100 and 1000, use scale K right.

Or a given number is divided into several groups with three digits per group, counting from the decimal point to right or left direction. If the first group consists of only one figure, a given number is set on the scale K left If it consists of two figures, a given number is set on the scale K middle. If three figures, on the scale K right.

Place the decimal point of the answer, taking one digit per group.

Example 50. $\sqrt[3]{2.62}=1.379$, $\sqrt[3]{2'620'000}=137.9$
$\sqrt[3]{0.002'62}=0.1379$

Move hairline to 262 on K left,
under hairline find 1.379 on D.

Example 51. $\sqrt[3]{26.2}=2.97$, $\sqrt[3]{26'200}=29.7$
$\sqrt[3]{0.000'026'2}=0.0297$

Move hairline to 262 on K middle,
under hairline find 2.97 on D.

Example 52. $\sqrt[3]{262}=6.4$, $\sqrt[3]{262'000}=64$,
$\sqrt[3]{0.000'000'262}=0.0064$

Move hairline to 262 on K right,
under hairline find 6.4 on D

(3) $\frac{3}{2}$ Power and $\frac{2}{3}$ Power

$\frac{3}{2}$ power and $\frac{2}{3}$ power are calculated by the use of the reference scales A and K.

Example 53. $4^{\frac{3}{2}}=8$

Move hairline to 4 on A left,
under hairline read answer as 8 on K left,

Example 54. $29.5^{\frac{2}{3}}=9.55$

Move hairline to 295 on K middle,
under hairline read answer as 9.55 on A left.

6. LOGARITHMS

(1) Common Logarithms

Common Logarithms are calculated to the base 10 including the integer (characterisic) and the decimal part (mantissa).

A slide rule gives only the mantissa of common logarithms; the characteristic can be calculated by the following formula:

(the number of places exceeding decimal point of a given number−1)

viz. the characteristic of any number greater than unity is always 1 less than the number of figures at the left of decimal point.

If given number is of n places under the decimal point, the characteristic is also negative; this is indicated by placing the negative sign or bar over the figure as $-n$ or $\bar{n}$.

The mantissa of a given number may be found by L and D scales in reference relation.

Example 55. $\log_{10} 3.14 = 0.497$

Move hairline to 314 on D,
under hairline read answer as 0.497 on L.

Example 56. $\log_{10} 0.000342 = 4.534$

Move hairline to 342 on D,
under hairline find 0.534 on L,
add characteristic $\bar{4}$, read answer as $\bar{4}.534$.

Example 57. $\log_{10} 887 = 2.948$

Move hairline to 887 on D,
under hairline find 0.948 on L,
add characteristic 2, read answer as 2.948.

(2) Natural Logarithms

Logarithms to the base of $e(\fallingdotseq 2.718)$ are called natural logarithms; they may be determined by multiplying by 2.3026 common logarithms according to the following formul

$$\log_e N = 2.3026 \times \log_{10} N$$

(3) Anti-Logarithms

The type form of $\log_{10}^{-1} x = a$ is calculated by the exact reverse procedure of the above examples. Take the mantissa only of a given number x and set it on the L scale. The significant figure of number of logarithm a is given on the D scale, opposite the mantissa on the L scale. When the characteristic is n, there will be $(n+1)$ figures before the decimal point in the answer. When the characteristic is n, the answer is of n places under the decimal point.

Example 58. $\log_{10}^{-1} 1.398 = 25$

Move hairline to 0.398 on L,
under hairline find 25 on D,
characteristic is 1,
there will be two figures before the decimal point,
thus read answer as 25.

(4) Exponent

Calculation of the type form of a^n is made by the following procedures.

Now, $a^n = x$ $\quad \therefore \log_{10} x = n \times \log_{10} a$

$\therefore x = \log_{10}^{-1}(n \times \log_{10} a)$

Find $\log_{10} a$,
calculate $n \times \log_{10} a$,
answer is given by $\log_{10}^{-1}(n \times \log_{10} a)$.

Example 59. $3.14^{2.5} = 17.46$

Move hairline to 314 on D,
under hairline read $0.497 (= \log_{10} 3.14)$ on L,
move hairline to 497 on D,
set 25 on CI under hairline,
opposite left index of C read $1.242 (= 25 \times \log_{10} 3.14)$ on D,
move hairline to 0.242 on L,
under hairline read $1746 (= \log_{10}^{-1}(2.5 \times \log_{10} 3.14))$ on D,
characteristic is 1, therefore there will be two figures before the decimal point,
then read answer as 17.46.

7. TRIGONOMETRIC FUNCTIONS

These computations usually can be obtained by the use

S, T_1, T_2 and C scales.

S scale gives the sines of angles ranging from 5.5° or 5.8° to 90°.

T_1 scale gives the tangents of angles ranging from 5.5° or 5.75° to 45°

T_2 scale gives the tangents of angles ranging from 45° to 84.2°.

(1) Sin θ

Example 60. $\sin 1.5° = 0.259$

Move hairline to 15 on S,
under hairline find 259 on C,
read answer as 0.259.

When using the S scale to read the value of $\sin\theta$, read the left index of C as 0.1 and the right index as 1.

Example 61. $\sin 30° \times 5 = 2.5$

Opposite 5 on D, set right index of C,
move hairline to 30 on S,
under hairline read answer as 2.5 on D.

Example 62. $\sin 24.4° \div 1.67 = 0.247$

Opposite left index of D, set left index of C,
move hairline to 244 on S,
set 167 on C under hairline,
opposite left index of C find 247 on D,
read answer as 0.247.

Example 63. $3.06 \div \sin 43° = 4.49$

Move hairline to 306 on D,
set 43 on S under hairline,
opposite right index of C, read answer as 4.49 on D.

(2) How to Use Gauge Mark $\rho°$

The sines and tangents of angles smaller than 6° can be found by the following approximation.

$$\sin\theta° \fallingdotseq \tan\theta° \fallingdotseq \theta \text{ (in radians)}.$$

Therefore, to find the sine and tangent of an angle smaller than 6°, find the value of the angle in radians, They are obtained by the use of $\rho°$ on the C scale.

$$\rho° \text{ .....} \frac{180°}{\pi} = 57.2958° = 1 \text{ radian}$$

Example 64. $\sin 1.5° = 0.0262$

Move hairline to 15 on D,
set $\rho°$ on C under hairline,
opposite right index of C, find 262 on D,
read answer as 0.0262.

The position of the decimal point is estimated as follows:

$$1° \fallingdotseq 0.02$$

(3) Cos θ

The value of $\cos\theta$ is found by reading the sines of the complementary angles as $\cos\theta = \sin(90° - \theta)$.

The red numbers on the S scale represent the complements of the angles as shown by the corresponding black numbers on these scales. The red numbers on the S scale are used with the C scale to find the values of the cosines of angles. When using the red S scale to read the value of $\cos\theta$, read the left index of C as 0.1 and the right index as 1.

Example 65. $\cos 30° = 0.866$

Move hairline to 30 on S (red),
under hairline find 866 on C,
read answer as 0.866.

Example 66. $\cos x^\circ = 0.413$ $x = 65.6^\circ$

Move hairline to 413 on C,
read answer as 65.6 on S (red) under hairline.

(4) Sine Proportions

The calculation of sine proportion is worked out by refering to S and D scales. In Fig. 1, there is the following formula.

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

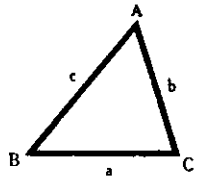

Fig. 1

Therefore, opposite a, b and c on the D scale, set A, B and C on the S scale respectively.

Example 67. In Fig. 1, find a and c, given $A=80^\circ$, $B=35^\circ$, $C=65^\circ$ and $b=25$.
Answer $a=42.9$, $c=39.5$

Move hairline to 25 on D,
set 35 on S under hairline,
move hairline to 80 on S,
under hairline find 429 on D,
read answer as 42.9.
Move hairline to 65 on S,
under hairline find 395 on D,
read answer as 39.5.

(5) Tan θ

Example 68. $\tan 32.5^\circ = 0.637$

Move hairline to 325 on T_1,
under hairline find 637 on C,
read answer as 0.637.

When using the T_1 scale to read the value of $\tan\theta$, read the left index of C as 0.1 and the right index as 1.

Tangents of angles greater than 45° are calculated by the use of the T_2 scale.

Example 69. $\tan 62^\circ = 1.88$

Move hairline to 62 on T_2,
under hairline read answer as 1.88 on C.

When using the T_2 scale to read the value of $\tan\theta$, read the left index of C as 1 and the right index as 10.

Or to find the value of the tangents of angles greater than 45° read the reciprocals of the tangents of the complementary angles as $\tan\theta = \frac{1}{\tan(90^\circ-\theta)}$.

The red numbers on the T scales represent the complements of the angles as shown by the corresponding black numbers on this scale. Therefore, the tangents of angles greater than 45 degrees can be read directly between the red numbers on the T_2 scale and DI or CI scale. When using the red T scales to read the value of $\tan\theta$, read the right index of DI as 1 and the left index as 10.

Example 70. $\tan 62^\circ = 1.88$

Set C index even with D index,
move hairline to 62 on T_2(red),
under hairline read answer as 1.88 on DI.

(6) Other Trigonometric Functions

To get $\cot\theta$ $\sec\theta$ and $\operatorname{cosec}\theta$, use the following formulae:

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

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

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

(7) Solutions of Right Triangle and Vector Problems

By the co-operation of S, T and DI scales, solutions of the right triangle and vector problems can be obtained.

In the right triangle △ABC (in Fig. 2), there is the following formula:

$$c\cdot\sin\theta = a\cdot\tan\theta = b$$

$$\therefore \quad \frac{\sin\theta}{\frac{1}{c}} = \frac{\tan\theta}{\frac{1}{a}} = \frac{1}{\frac{1}{c}}$$

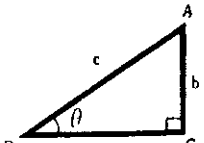

Fig. 2

Therefore, move the hairline to b on the DI scale, set the right or left index of the C scale under the hairline, move the hairline to a on the DI scale, under the hairline read θ on the T scale, move the hairline to θ on the S scale, under hairline read c on the DI scale.

Example 71. In Fig. 2. find c and ∠B, given a=2.3 and b=1.8.

Answer c=2.92, ∠B=38.08°

Move hairline to 18 on DI,
set right index of C under hairline,
move hairline to 23 on DI,
under hairline read answer as 3808 = ∠B on T,
move hairline to 3808 on S,
under hairline read answer as 2.92=c on DI.

Example 72. $\sqrt{2.54^2+1.65^2}=3.03$

$2.54+j1.65=3.03\ \underline{/33^\circ}$

Move hairline to 165 on DI,
set right index of C under hairline,
move hairline to 254 on DI,
under hairline read answer as 33 on T,
move hairline to 33 on S,
under hairline read answer as 3.03 on DI.

Example 73. Analyze the following vector.

Answer x=5.2, y=3.38 $6.20\ \underline{/33^\circ}=5.20+j3.38$

Move hairline to 620 on DI,
set 33 on S under hairline,
move hairline to 33 on T,
under hairline read answer as
5.20=x on DI,
move hairline to right index of C,
under hairline read answer as 3.38=y on DI.

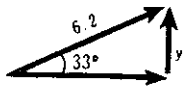

Fig. 3

8. HOW TO USE LL SCALES

(1) Explanation of LL Scales

LL represent that the scale is a logarithm of a logarithm. There are two groups of LL scales. One is LL_n scales (LL_0, LL_1, LL_2 and LL_3) ranging from 1.001 to 10^5 or 2×10^4 for the computation of the type form of a^{+n}. The other is LL-scales ($LL_{\bar{0}}$, $LL_{\bar{1}}$, $LL_{\bar{2}}$ and$LL_{\bar{3}}$) called Reciprocal LL_n scales ranging from 10^{-5} or 5×10^{-5} to 0.999 for the computation of the type form of a^{-n}.

Construction of LL scales { LL_n group...LL_0, LL_1, LL_2, LL_3 ; $LL_{\bar{n}}$ group...$LL_{\bar{0}}$, $LL_{\bar{1}}$, $LL_{\bar{2}}$, $LL_{\bar{3}}$ }

These LL scales are really divisions of one long Log Log scale. And the next scale to LL_0 or $LL_{\bar{0}}$ scale might be

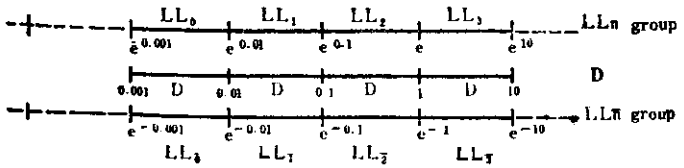

Fig. 4

considered common logarithmic scale D. Therefore, eight LL scales as shown in Fig. 4 are considered to cover the complete range of the LL scales.

As shown in Fig. 4, the LL_n and $LL_{\bar{n}}$ scales are in a reciprocal relation respectively. This arrangement can be used very conveniently for calculations of powers, roots of numbers, and hyperbolic functions. Usually, general slide rules have three LL scales (LL_1, LL_2 and LL_3). as on this rule.

(2) Natural Logarithms

Set the hairline to the given number N on the LL scale, $\log_e N$ will be found under the hairline on the D scale.

The position of the decimal point is determined as follows:

When N is set on { the LL_3 scale / the LL_2 scale } ... { one digit at the left / one digit at the right } of the decimal point,

when N is set on { the LL_1 scale / the LL_0 scale } ... { two digits at the right / three digits at the right } of the decimal point,

when N is set on { the $LL_{\bar{3}}$ scale / the $LL_{\bar{2}}$ scale } ... { one digit at the left / one digit at the right } of the decimal point and place the negative sign before the figures.

when N is set on { the $LL_{\bar{1}}$ scale / the $LL_{\bar{0}}$ scale } ... { two digits at the right / three digits at the right } of the decimal point and place the negative sign before the figures.

Example 74. $\log_e 5 = 1.609$

Move hairline to 5 on LL_3,
under hairline read answer as 1.609 on D.

Example 75. $\log_e 2 = 0.693$

Move hairline to 2 on LL_2,
under hairline find 693 on D,
read answer as 0.693.

Example 76. $\log_e 1.03 = 0.0296$

Move hairline to 1.03 on LL_1,
under hairline find 296 on D,
read answer as 0.0296.

Example 77. $\log_e 0.23 = -1.47$

Move hairline to 0.23 on $LL_{\bar{3}}$,
under hairline find 147 on D,
read answer as -1.47.

Example 78. $\log_e 0.625 = -0.47$

Move hairline to 0.625 on $LL_{\bar{2}}$,
under hairline find 47 on D,
read answer as -0.47.

Example 79. $\log_e 0.955 = -0.0461$

Move hairline to 0.955 on $LL_{\bar{1}}$,
under hairline find 461 on D,
read answer as -0.0461.

(3) Powers and Roots

The type form of $a^{\pm n}$ or $a^{\pm\frac{1}{n}}$ is calculated by the use of the LL scales in an operation similar to multiplication and division.

Example 80. $4.25^{2.12} = 21.5$, $4.25^{-2.12} = 0.0466$

Move hairline to 4.25 on LL_3,
set left index of C under hairline,
move hairline to 212 on C,
under hairline read answer as 21.5 on LL_3,
under hairline read answer as 0.0466 on $LL_{\bar{3}}$.

Example 81. $1.96^{2.3} = 4.70$, $1.96^{-2.3} = 0.213$

Move hairline to 1.96 on LL_2,

set right index of C under hairline,
move hairline to 23 on C,
under hairline read answer as 4.70 on LL_3,
under hairline read answer as 0.213 on $LL_{\overline{3}}$.

Example 82. $1.02^{24.5}=1.624$, $1.02^{-24.5}=0.616$

Move hairline to 1.02 on LL_1,
set left index of C under hairline,
move hairline to 245 on C,
under hairline read answer as 1.624 on LL_3,
under hairline read answer as 0.616 on $LL_{\overline{3}}$.

Example 83. $11.4^{0.7}=5.50$, $11.4^{-0.7}=0.182$

Move hairline to 11.4 on LL_3,
set 7 on CI under hairline,
move hairline to left index of C,
under hairline read answer as 5.50 on LL_2,
under hairline read answer as 0.182 on $LL_{\overline{3}}$.

Example 84. $330^{\frac{1}{6.3}}=2.55$, $330^{-\frac{1}{6.3}}=0.392$

Move hairline to 330 on LL_3,
set 62 on C under hairline,
move hairline to right index of C,
under hairline read answer as 2.55 on LL_2,
under hairline read answer as 0.392 on $LL_{\overline{3}}$.

Example 85. $28.5^{\frac{2.91}{3.41}}=17.4$, $28.5^{-\frac{2.91}{3.41}}=0.0574$

Move hairline to 28.5 on LL_3,
set 341 on C under hairline,
move hairline to 2.91 on C,
under hairline read answer as 17.4 on LL_3,
under hairline read answer as 0.0574 on $LL_{\overline{3}}$.

Example 86. $0.795^{1.4}=0.725$, $0.795^{-1.4}=1.379$

Move hairline to 0.795 on $LL_{\overline{2}}$,

set left index of C under hairline,
move hairline to 14 on C,
under hairline read answer as 0.725 on $LL_{\overline{2}}$,
under hairline read answer as 1.379 on LL_2.

Example 87. $0.795^{14}=0.0402$, $0.795^{-14}=24.9$

Move hairline to 0.795 on $LL_{\overline{2}}$,
set left index of C under hairline,
move hairline to 14 on C,
under hairline read answer as 0.0402 on $LL_{\overline{3}}$,
under hairline read answer as 24.9 on LL_3.

Example 88. $e^{1.96}=7.10$, $e^{-1.96}=0.1408$

Move hairline to 196 on D,
under hairline read answer as 7.10 on LL_3,
under hairline read answer as 0.1408 on $LL_{\overline{3}}$.

Example 89. $e^{0.94}=2.56$, $e^{-0.94}=0.39$

Move hairline to 94 on D,
under hairline read answer as 2.56 on LL_2,
under hairline read answer as 0.39 on $LL_{\overline{2}}$.

Example 90. $e^{0.056}=1.0576$, $e^{-0.056}=0.9455$

Move hairline to 56 on D,
under hairline read answer as 1.0576 on LL_1,
under hairline read answer as 0.9455 on $LL_{\overline{1}}$,

(4) Hyperbolic Functions

Hyperbolic functions are computed from the following formulas; in these cases, we use the LL_n and $LL_{\overline{n}}$ scales.

$$\sinh x=\frac{e^x-e^{-x}}{2}$$

$$\cosh x=\frac{e^x+e^{-x}}{2}$$

$$\tanh x=\frac{e^{2x}-1}{e^{2x}+1}$$

Example 91. $\sinh 0.802=0.891$
$\cosh 0.802=1.339$
$\tanh 0.802=0.665$

Move hairline to .802 on D,
under hairline find $2.23=e^{0.802}$ on LL_3,
under hairline find $4.48=e^{-0.802}$ on $LL_{\overline{3}}$.
Move hairline to $1.604=2\times0.802$ on D,
under hairline find $4.975=e^{2\times0.802}$ on LL_3.

$$\therefore \quad \sinh 0.802=\frac{2.23-0.448}{2}=0.891$$

$$\cosh 0.802=\frac{2.23+0.448}{2}=1.339$$

$$\tanh 0.802=\frac{4.975-1}{4.975+1}=0.665.$$

10. HOW TO USE GAUGE MARKS

There are the following gauge marks on our slide rules

(1) **$c\fallingdotseq1.128$**

The c mark is placed on the C and D scales at 1.128, and is used for the calculation of a circle area.

Example 92. Find the area of a circle with its diameter of 1.5cm. Answer $1.77\,cm^2$

Move hairline to 15 on D,
set c on C under hairline,
opposite left index of C read answer as 1.77 on A left.

(2) **$\rho^\circ\fallingdotseq57.2958$**

The ρ° mark is placed on the C and D scales at 5.72958, and is used for converting an angle from degrees to radians.

Example 93. $2.4^\circ=0.0419$ radians

Move hairline to right index of D,
set ρ° on C under hairline,
move hairline to 24 on C,
under hairline find 419 on D,
read answer as 0.0419 radians.

[$1^\circ\fallingdotseq0.02$ radians (approximately)
$\therefore\ 2.4^\circ\fallingdotseq0.02\times2.4=0.048$ radians.]

(3) **$\pi\fallingdotseq3.1416$**

The π mark is placed on the C, D, DF and CF scales at 3.1416, and shows the ratio of the circumference of a circle to its diameter.

(4) **$\varepsilon\fallingdotseq2.718$**

The ε mark is placed on the LL_2 and LL_3 scales at 2.718, and shows the value of the base of natural logarithms.

(5) **$1/\varepsilon\fallingdotseq0.3679$**

The $1/\varepsilon$ mark is placed on the LL_2 and LL_3 scales at 0.3679, and shows the value of the reciprocal of ε.

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