INSTRUCTIONS

PROFESSIONAL SLIDE RULE

MODEL NO. 1570

SCIENTIFIC INSTRUMENTS CO.
BERKELEY CALIF.

CONTENTS

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FOR THE USE OF YOUR SLIDE RULE

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1. GENERAL DESCRIPTION

This slide rule has been designed for expert electrical engineer to simplify the various calculations occurred frequently in electricity, namely not only the computation of multiplication and division can be done with the A, B, C, D, CI, DF and CF scales, but also the LL_3, LL_2 and LL_1' scales make it possible to obtain the result of a^n, e^x and $\log_e N$. Moreover, the P, Q and P′ scales are essential for vector computation, the Sh_2, Sh_1 and Th scales for hyperbolic function.

2. SCALE ARRANGEMENT AND USAGE

(Front Face) Sr, Sθ, P′, P, Q, CF, CI, C, D, DF, LL_2, LL_3
(Back Face) Sh_2, Sh_1, A, B, K, Th, C, D, Tr_1, Tr_2, db.

(a) Sr and Sθ

These scales are used to obtain the sine and cosine of an angle, co-operate with the P and Q scales. Angles are graduated at degree and its decimal fraction in the Sr scale, and at radian in the Sθ scale. Thus conversion from degree to radian or its reverse process is made by the use of these scales.

(b) P, Q and P′

The computation of the vector can be conveniently done by these scales as ordinary multiplication and division done by the C and D scales.

(c) LL_3, LL_2 and LL_1'

The LL_3 and LL_2 are called the Log Log scales and are used to find the values of the type form of a^n, e^x and $\log_e N$.

LL_1', which as an extension scale of C, is marked in red at the right end of it, substitutes the ordinary LL_1 scale.

(d) Sh1 and Sh2

These scales make it possible to compute the sine-hyperbolic function, which is frequently necessary in alternating current theory.

(e) Th

This gives the value of the tangent-hyperbolic function.

(f) Tr1 and Tr2

These scales are used in the computation of the tangent of an angle from 0.1 to 0.8 radians, and from 0.8 to 1.472 radians respectively.

(g) db

This decibel scale is useful in the computation of electric communication circuit. Moreover this equaly subdivided scale can be used as ordinary mantissa scale to obtain the common logarithms of a number.

(h) A, B, C, D, CI, DF and CF

Of these scales, the DF and CF scales are the D and C scales folded at π, so every number on these scales is equal to the number on the D and C scales multiplied by π.

3. TRIGONOMETRIC FUNCTIONS

(1) Sin θ

The sine of an angle, either in degree or in radian can be directly read on Sθ or Sr scale.

Example 1. $\sin 51.8^\circ = 0.786$

Move hairline to 51.8 on Sθ,
under hairline find 7.86 on P,
read answer as 0.786.

Example 2. $\sin 0.665 = 0.617$

Move hairline to 0.665 on Sr,
under hairline find 6.17 on P,
read answer as 0.617.

(2) Cos θ

Example 3. $\cos 51.8^\circ = 0.618$

Move hairline to 51.8 on Sθ (red),
under hairline find 6.18 on P,
read answer as 0.618.

Example 4. $\cos 0.665 = 0.787$

Move hairline to 0.665 on Sr,
set left index of Q under hairline,
opposite right index of P find 7.87 on Q,
read answer as 0.787.

(3) Conversion between Degree and Radian

Conversion from degree to radian or its reverse process is made by using the Sr and Sθ scales.

Example 5. $53^\circ = 0.925$ radians

Move hairline to 53 on Sθ,
under hairline read answer as 0.925 on Sr.

Example 6. 0.52 radians $= 29.8^\circ$

Move hairline to 0.52 on Sr,
under hairline read answer as 29.8 on Sθ.

In the case of conversion of a small angle, move the decimal point one place to the right, perform the oparation as is explained above, and read the answer moving the decimal point one place lower.

Example 7. 0.06 radians=3.44°
Move hairline to 0.6 on Sr,
under hairline find 34.4 on Sθ,
read answer as 3.44.

(4) Tan θ

The Tr_1 and Tr_2 scales represent a single scale of angles ranging from 0.1 to 1.472 radians.

When using the Tr_1 scale to read the value of $\tan\theta$, read the left index of D as 0.1 and the right index as 1, and using the Tr_2 scale to read the value of $\tan\theta$, read the left index of D as 1 and the right index as 10.

Example 8. $\tan 0.35=0.365$
Move hairline to 0.35 on Tr_1,
under hairline find 3.65 on D,
read answer as 0.365.

Example 9. $\tan 1.17=2.36$
Move hairline to 1.17 on Tr_2,
under hairline read answer as 2.36 on D.

4. VECTOR PROBLEMS

(1) The Absolute Value of Vector

The absolute value of vector, represented in the type from of $a+jb$, is equal to $\sqrt{a^2+b^2}$, and by the use of the P, Q

and P′ scales this value can be computed very easily in the same operation as ordinary multiplication and division. Namely set zero on the Q scale to a on the P scale, opposite b on the Q scale read $\sqrt{a^2+b^2}$ on the P scale. When b on the Q scale runs off the P scale, then set 10 on the Q scale to a on the P scale, and opposite b on the Q scale read the answer on the P′ scale.

Example 10. Find the absolute value of $3+j4$.

Opposite 3 on P, set left index of Q,
move hairline to 4 on Q,
under hairline read answer as 5 on P.

Example 11. $\sqrt{8.76^2+9.32^2}=12.79$

Opposite 8.76 on P, set right index of Q,
move hairline to 9.32 on Q,
under hairline read answer as 12.79 on P′.

The computation of the type form of $\sqrt{a^2-b^2}$ can be done in the same way.

Example 12. $\sqrt{10.53^2-5.96^2}=8.68$

Move hairline to 10.53 on P′,
set 5.96 on Q under hairline,
opposite right index of Q, read answer as 8.68 on P.

Example 13. $\sqrt{93.4^2-41.8^2}=83.5$

Calculate as $10\times\sqrt{9.34^2-4.18^2}$
move hairline to 9.34 on P,
set 4.18 on Q under hairline,
opposite left index of Q, find 8.35 on P,
read answer as $10\times8.35=83.5$.

(2) Phase Angle of Vector

In the vector of the type form of $a+jb$, the phase angle θ is represented as follows:

$$\theta=\tan^{-1}\frac{b}{a}$$

Example 14. $\tan^{-1}\frac{3.6}{2.5}=0.964$

Move hairline to 3.6 on D,
set 2.5 on C under hairline,
move hairline to left index of C,
under hairline read 0.964 on Tr_2.

Example 15. $\tan^{-1}\frac{2.5}{3.6}=0.607$

Move hairline to 2.5 on D,
set 3.6 on C under hairline,
move hairline to right index of C,
under hairline read 0.607 on Tr_1.

(3) Conversion of Coordinate System

From the following relations;

$$a+jb=\sqrt{a^2+b^2}\,\underline{/\tan^{-1}\frac{b}{a}}=R\underline{/\theta}$$

here $R=\sqrt{a^2+b^2}$

$$\theta=\tan^{-1}\frac{b}{a}$$

$$R\underline{/\theta}=R\cdot\cos\theta+jR\cdot\sin\theta$$

the conversion of vector in polar coordinate system to rectangular coordinate system and its reverse computation can be easily done.

Example 16. $-7.5+j6.0=9.6\underline{/\pi-0.675}$

This is the example of conversion of $a+jb$ to polar coordinate system.

Opposite 7.5 on P, set left index of Q,
move hairline to 6.0 on Q,
under hairline read absolute value as 9.6 on P.

Move hairline to 6.0 on D,
set 7.5 on C under hairline,
move hairline to right index of C,
under hairline read 0.675 on Tr_1,
thus the phase angle is equal to $\pi-0.675$.

Example 17. $25/\underline{52^\circ}=15.4+j19.7$

This is an example of conversion of polar coordinate system to $a+jb$.

Move hairline to 52 on Sθ,
under hairline read $\sin 52^\circ=0.788$ on Q,
move hairline to 52 on Sθ (red),
under hairline read $\cos 52^\circ=0.616$ on P,
thus, real part is calculated as $25\times0.616=15.8$ and imaginary part $j25\times0.788=j19.7$.

(4) Multiplication and Division of Vectors

Multiplication and Division of two vectors have been computed from the following formulas:

$$R_1/\underline{\theta_1}\times R_2/\underline{\theta_2}=R_1\cdot R_2/\underline{\theta_1+\theta_2}$$

$$\frac{R_1/\underline{\theta_1}}{R_2/\underline{\theta_2}}=\frac{R_1}{R_2}/\underline{\theta_1-\theta_2}$$

Example 18. $\dfrac{3-j2}{8+j4}=0.404\backslash\underline{1.052}$

$$\frac{3-j2}{8+j4}=\frac{\sqrt{3^2+2^2}/\underline{\tan^{-1}\left(\frac{-2}{3}\right)}}{\sqrt{8^2+4^2}/\underline{\tan^{-1}\left(\frac{4}{8}\right)}}=\frac{3.61/-0.588}{8.94/0.464}$$

$$=0.404/\underline{-0.588-0.464}$$

$$=0.404/\underline{-1.052}=0.404\backslash\underline{1.052}$$

Example 19. Calculate the current in an electric circuit which impedance is $4+j2.6$ and the potenti-

al difference between its terminals is $5+j9$.

Answer $\dot{I}=1.907+j1.013$

$$\dot{I}=\frac{\dot{E}}{\dot{Z}}=\frac{5+j9}{4+j2.6}=\frac{\sqrt{5^2+9^2}\angle\tan^{-1}\left(\frac{9}{5}\right)}{\sqrt{4^2+2.6^2}\angle\tan^{-1}\left(\frac{2.6}{4}\right)}$$

$$=\frac{10.3/1.064}{4.77/0.576}$$

$$=\frac{10.3}{4.77}/1.064-0.576$$

$$=2.16/0.488$$

$$\therefore \quad =2.16\times\cos 0.488\times j2.16\times\sin 0.488$$

$$=2.16\times 0.883+j2.16\times 0.469$$

$$\therefore \quad \dot{I}=1.907+j1.013$$

Example 20. Compute the resultant current $\dot{I}$, of $\dot{I}_1=2+j3$ and $\dot{I}_2=3+j4$ in polar coodinate.

Answer $\dot{I}=8.60/0.95$

$$\dot{I}=\dot{I}_1+\dot{I}_2=(2+j3)+(3+j4)=5+j7$$

$$=\sqrt{5^2+7^2}\angle\tan^{-1}\left(\frac{7}{5}\right)$$

$$\therefore \quad \dot{I}=8.60/0.95$$

5. HYPERBOLIC FUNCTIONS

The logarithmic scales Sh_1, Sh_2 and Th are used for the computation of hyperbolic function.

(1) Sinh x

The Sh_1 and Sh_2 scales give the value of $\sinh x$. When using the Sh_1 scale to read the value of $\sinh x$, read the left index of D as 0.1 and the right index as 1, and using the Sh_2 scale to read the value of $\sinh x$, read the left index of D as 1 and the right index as 10.

Example 21. $\sinh 0.362 = 0.370$

Move hairline to 0.362 on Sh_1,
under hairline find 3.70 on D,
read answer as 0.370.

Example 22. $\sinh 2.56 = 6.42$

Move hairline to 2.56 on Sh_2,
under hairline read answer as 6.42 on D.

(2) Tanh x

The Th scale gives the value of $\tanh x$. When using the Th scale to read the value of $\tanh x$, read the left index of C as 0.1 and the right index as 1.

Example 23. $\tanh 0.183 = 0.181$

Move hairline to 0.183 on Th_1,
under hairline find 1.81 on C,
read answer as 0.181.

(3) Cosh x

The value of $\cosh x$ can be computed from the following formula:

$$\cosh x = \frac{\sinh x}{\tanh x}$$

Example 24. $\cosh 0.575 = 1.170$

Move hairline to 0.575 on Sh_1,
set 0.575 on Th under hairline,
opposite left index of C read answer as 1.170 on D.

6. HYPERBOLIC FUNCTIONS OF COMPLEX ANGLES

Hyperbolic functions of complex angles are given from the following formulas:

(a) $\sinh(a+jb) = \sinh a \cdot \cos b + j \cosh a \cdot \sin b$
$= \sqrt{\sinh^2 a + \sin^2 b} \angle \tan^{-1}(\tan b / \tanh a)$

(b) $\cosh(a+jb) = \cosh a \cdot \cos b + j \sinh a \cdot \sin b$

$$=\sqrt{\sinh^2 a+\cos^2 b}\ \underline{/\tan^{-1}(\tan b\cdot\tanh a)}$$

(c) $\tanh(a+jb)=\sinh(a+jb)/\cosh(a+jb)$

$$=\sqrt{\frac{\sinh^2 a+\sin^2 b}{\sinh^2 a+\cos^2 b}}\ \underline{/\tan^{-1}\left(\frac{\sin 2b}{\sin 2a}\right)}$$

(d) $\tanh^{-1}(a+jb)=x+jy$

Here, $x=\frac{1}{2}\log_e R$, $y=\frac{\theta}{2}$

and $\underline{\frac{1+(a+jb)}{1-(a+jb)}=R/\theta}$

(1) Sinh $(a+jb)$

Example 25. $\sinh(0.43+j0.68)=0.769/1.106$

$\sinh 0.43=0.443$

Move hairline to 0.43 on Sh_1,
under hairline find 4.43 on D,
read answer as 0.443.

$\sqrt{\sinh^2 0.43+\sin^2 0.68}=\sqrt{0.443^2+\sin^2 0.68}=0.769$

move hairline to 0.68 on Sr,
set left index of Q under hairline,
move hairline to 4.43 on Q,
under hairline find 7.69 on P,
read answer as 0.769.

$\tan^{-1}\left(\frac{\tan 0.68}{\tanh 0.43}\right)=1.106$

Move hairline to 0.68 on Tr_1,
set 0.43 on Th under hairline,
move hairline to left index of C,
under hairline read answer as 1.106 on Tr_2.

(2) Cosh $(a+jb)$

Example 26. $\cosh(0.75-j1.24)=0.884\angle 1.075$

$\sinh 0.75=0.822$

Move hairline to 0.75 on Sh_1,

under hairline find 8.22 on D,
read answer as 0.822.

$\sqrt{\sinh^2 0.75+\cos^2 1.24}=\sqrt{0.822^2+\cos^2 1.24}=0.884$

Move hairline to 1.24 on Sr,
set right index of Q under hairline,
move hairline to 8.22 on P,
under hairline find 8.84 on Q,
read answer as 0.884.

$\tan^{-1}(-\tan 1.24\cdot\tanh 0.75)=-1.075$

Move hairline to 1.24 on Tr_2,
set right index of C under hairline,
move hairline to 0.75 on Th,
under hairline find 1.075 on Tr_2,
read answer as -1.075.

(3) $\mathrm{Tanh}^{-1}(a+jb)$

Exampl 27. $\tanh^{-1}(0.2+j0.4)=0.1735+j0.393$

$$\frac{1+(0.2+j0.4)}{1-(0.2+j0.4)}=\frac{1.2+j0.4}{0.8-j0.4}=\frac{\sqrt{1.2^2+0.4^2}/\tan^{-1}(0.4/1.2)}{\sqrt{0.8^2+0.4^2}/\tan^{-1}(-0.4/0.8)}$$

$\sqrt{1.2^2+0.4^2}=1.265$

Move hairline to 12 on P′,
set left index of Q under hairline,
move hairline to 4 on Q,
under hairline find 12.65 on P′,
read answer 1.265.

$\tan^{-1}\left(\frac{0.4}{1.2}\right)=0.322$

Move hairline to 4 on D,
set 1.2 on C under hairline,
move hairline to left index of C,
under hairline read answer as 0.322 on Tr_1.

$\sqrt{0.8^2+0.4^2}=0.894$

Opposite 8 on P, set left index of Q,
move hairline to 4 on Q,
under hairline find 8.94 on P,
read answer as 0.894.

$\tan^{-1}\left(\frac{-0.4}{0.8}\right)=-0.464$

Move hairline to 4 on D,
set 8 on C under hairline,
move hairline to right index of C,
under hairline find 0.464 on Tr_1,
read answer as -0.464.

$$\therefore \quad \frac{1.265/0.322}{0.894/-0.464}=\frac{1.265}{0.894}/0.322+0.464=1.415/0.786$$

$$x=\frac{1}{2}\log_e 1.415=\frac{1}{2}\times 0.347=0.1735$$

Move hairline to 1.415 on LL_2,
set 2 on C under hairline,
opposite left index of C, find 1.735 on D,
read answer as 0.1735.

$$y=\frac{\theta}{2}=\frac{0.786}{2}=0.393$$

Thus the answer is;

$$\tanh^{-1}(0.2+j0.4)=0.1735+j0.393$$

7. DECIBEL CALCULATIONS

In the electric communication circuit, let voltage and current at input side be V_1 and I_1, and those at output side be V_2 and I_2, the decibel for voltage ratio $db_{(V)}$ and the decibel for current ratio $db_{(I)}$ are as follows:

$$db_{(V)}=20\log_{10}\frac{V_2}{V_1},$$

$$db_{(I)}=20\log_{10}\frac{I_2}{I_1}$$

When V_2, V_1 or I_2, I_1 are given, the ratio $\frac{V_2}{V_1}$ or $\frac{I_2}{I_1}$ is obtained by using the C and D scales, and the decibel of the ratio $\frac{V_2}{V_1}$ or $\frac{I_2}{I_1}$ is read on the db scale.

Example 28. In a ratio frequency amplifier the input voltage is 5 volts. The output voltage is 12 volts. Find the decibel voltage gain.
Answer 7.6 db.

Move hairline to 1.2 on D,
set 5 on C under hairline,
move hairline to right index of C,
under hairline read answer as 7.6 on db.

Example 29. Find the decibel current gain $\frac{I_2}{I_1}=1.07$.
Answer 0.59 db.

Move hairline to 1.07 on D,
under hairline read answer as 0.59 on db.

8. HOW TO USE LL SCALES

(1) Explanation of LL Scales

LL represent that the scale is a logarithm of a logarithm. This rule has LL_n scales (LL_2 and LL_3) ranging from 1.105 to 20000 for the computation of the type form of a^n.

(2) Natural Logarithms

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

Determining the position of the decimal point is as follows:

When N is set on $\left\{\begin{matrix}\text{the LL}_3\text{ scale}\\ \text{the LL}_2\text{ scale}\end{matrix}\right\}\cdots\left\{\begin{matrix}\text{one digit at the left}\\ \text{one digit at the right}\end{matrix}\right\}$ of the decimal point.

Example 30. $\log_e 5=1.609$

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

Example 31. $\log_e 2=0.693$

Move hairline to 2 on LL_2,
under hairline find 6.93 on D,
read answer as 0.693.

(3) Powers and Roots

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

Example 32. $4.25^{2.12}=21.5$

Move hairline to 4.25 on LL_3,
set left index of C under hairline,
move hairline to 2.12 on C,
under hairline read answer as 21.5 on LL_3.

Example 33. $1.96^{2.3}=4.70$

Move hairline to 1.96 on LL_2,
set right index of C under hairline,
move hairline to 2.3 on C,
under hairline read answer as 4.70 on LL_1,

Example 34. $11.4^{0.7}=5.50$

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_3.

Example 35. $e^{1.96}=7.10$

Move hairline to 1.96 on D,

under hairline read answer as 7.10 on LL_3.

Example 36. $e^{0.94}=2.56$

Move hairline to 9.4 on D,

under hairline read answer as 2.56 on LL_3.

(4) How to Use LL_1' Scale

As an extension of the C scale there is a very short scale at the right end of the C scale marked from 1 to 1.1 in red. This scale called LL_1' is invented in our laboratory to substitute the several lower LL scales in calculation of $\log_e N$ and e^x etc.

(Natural Logarithms)

When x is nearly equal to 1, its natural logarithms are approximately equal to $x-1$. But, using the LL_1' scale we can obtain its value more precisely. The procedure is:

Move the hairline to $(x-1)$ on the D scale, set x on the LL_1' scale under the hairline, opposite the right index of the C scale, read the answer on the D scale.

Example 37. $\log_e 1.05=0.0488$

Move hairline 0.05(=1.05−1) on D,

set 1.05 on LL_1' under hairline,

read answer as 0.0488.

(e^x)

When x is nearly equal to zero, the value of e^x is approximately equal to $(1+x)$. Using the LL_1' scale we can obtain is precisely:

Opposite x on the D scale, set the right index of the C scale, move the hairline to $(1+x)$ on the LL_1' scale, under

the hairline read the fractional part of the answer.

Example 38. $e^{0.095}=1.0995$

Opposite 9.5 on D, set right index of C,
move hairline to 1.095 on LL_1',
under hairline find 9.95 on D,
read answer as $1+0.0995$.

9. HOW TO USE GAUGE MARKS

There are the following gauge marks on our slide rules.

(1) $c \fallingdotseq 1.128$

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 39. Find the area of a circle with its diameter of 1.5 cm. Answer 1.77 cm^2

More hairline to 1.5 on D,
set c on C under hairline,
opposite left index of C read answer as 1.77 on A left.

(2) $c_1 \fallingdotseq 3.568$

The c_1 mark is placed on the C and D scales at 3.568, and is used for calculation of a circle area.

Example 40. Find the area of a circle with its diameter of 5.1 cm. Answer 20.4 cm^2

Move hairline to 5.1 on D,
set c_1 on C under hairline,
opposite middle index of B read answer as 20.4 on A right.

(3) $\pi \fallingdotseq 3.1416$

The π mark is plased on the C, D, DF, CF, A and B scales

move hairline to 2.4 on C,
under hairline find 4.19 on D,
read answer as 0.0419 radians.
[$1^\circ \fallingdotseq 0.02$ radians (approximately)
$\therefore \quad 2.4^\circ \fallingdotseq 0.02 \times 2.4 = 0.048$ radians.]

— THE END —

APPENDIX

(1) Legend Numbers

There are the legend numbers on the right ends of your slide rules. The following is the brief description of the legend numbers.

scale mark	legend number	explanation
LL_3	1.0→10.0	.....When using the LL_3 scale to read the value of e^x, indicate the range of x which is set on the D scale, namely read the left index of D as 1.0 and the right index as 10.0.
LL_2	0.1→1.0	.....When using the LL_2 scale to read the value of e^x, read the left index of D as 0.1 and the right index as 1.0.
LL_1	0.01→0.1	.....When using the LL_1 scale to read the value of e^x, read the left index of D as 0.01 and the right index as 0.1.

(2) Scale Marks on Runner

To aid the operator in remembering, the scale marks are written on the runner glosses of Duplex type slide rule.

(3) Proper Care and Adjustment for Bamboo Slide Rule

Your slide rule should always be kept in a dry cool place and do you not expose slide rule to direct rays of the sun or extreme heat.

If the slide rule has to be kept in a damp place, or if the slide does not move with ease, it is good that some paraffin wax is applied to the tongues of the slide and the grooves of the stocks.

Dusts or stains on the surface of the slide rule can be removed with cloth moistened with small amount of linseed oil. Alcoholic must be avoided as it tends to dissolve celluloid.

If the slide is too stiff or too loose, loosen the screw first at one end of the top of the L-type bracket of the upper stock, moving that end a very slight amount either to decrease or to increase the pressure of the upper stock against the slide. Tighten the screw and repeat the per formance at the other end. Do not loosen both screws at the same time.