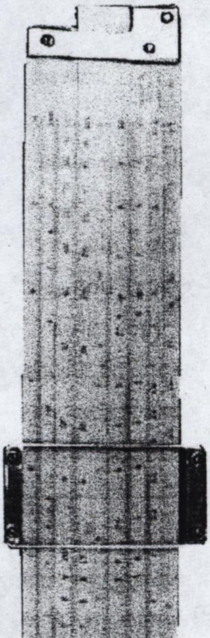
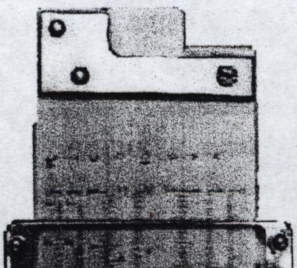
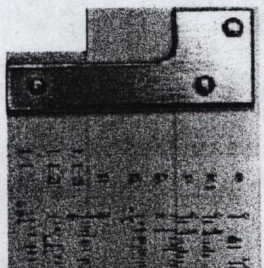


How to Use The Special Scales on SUN HEMMI 153 Slide Rule





How to Use The Special Scales
On SUN HEMMI 153 Slide Rule

Preface

SUN HEMMI 153 Slide Rule have 18 scales altogether, On the side 1, there are 9 scales: L, K, A, B, CI, C, D, T, G_θ scales; On the side 2, there are 9 scales: θ, R_θ, P, Q, Q', C, LL_3, LL_2, LL_1. The scales of 153 slide rule differ from most other slide rules. Besides the common scales L, K, A, B, CI, C, D, LL_3, LL_2, LL_1 scales, the 153 has seven special scales. That makes it possible to solve a right triangle for finding one side when known other two sides, evaluate sines, cosines, and tangents, and evaluate the hyperbolic functions sinh, cosh, and tanh using only seven scales. The special scales for trigonometric and hyperbolic function on 153 are θ, R_θ, P, Q, Q', T and G_θ. In this manual, we do not discuss the common scales anymore, but, just discuss the usage those relatives with the special scales.

I. Trigonometric Functions

For calculating the trigonometric functions, The 153 slide rule use the angle scales θ for degree measure, and the scale R_θ for radian measure in cooperation with un-logarithmic scales so called Square scales P and Q. On the P and Q scales have the same graduations, The P scale is for finding the sines, and the Q scale is for finding the cosines. And, the T scale on the reverse side for finding the tangents. Please pay attention, it should make sure the hairlines on the two side are on the right opposite position when find the tangents because the θ, R_θ scales are at the difference side with the T scale.

Ex. 1 find sin30°=? cos30°=? tg30°=? ctg30°=?

Move the hairline one 30° on θ scale, under the hairline, read P: 0.5 is the answer of sin30°, on the other side read the T: 0.577 is the answer of tg30°, pull the slide let left index Q:0 under the hairline, read the Q:0.866 is the answer of cos30°. $ctg\theta = \dfrac{1}{tg\theta}$, so, use of C and CI scale can find the ctg30°=1.732 easily.

i.e. sin30°=0.5, cos30°=0.866, tg30°=0.577, ctg30°=1.732

Ex. 2 find sin1.1=? cos1.1=? tg1.1=? ctg1.1=?

Move the hairline one 1.1 on R_θ scale, under the hairline, read P: 0.891 is the answer of sin1.1, on the other side read the T: 1.964 is the answer of tg1.1, pull the slide let left index Q:0 under the hairline, read the Q:0.454 is the answer of cos1.1. $ctg\theta = \dfrac{1}{tg\theta}$, so, use of C and CI scale can find the ctg1.1=0.509 easily.

i.e. sin30°=0.891, cos30°=0.454, tg30°=1.964, ctg30°=0.509

II. Vector Calculation

A vector can be given in two forms, one form is rectangular coordinates A+jB, the other form is polar coordinates $Z\underline{|\theta}$. This two forms can be converted each other.

Find Absolute Value

A vector is given in rectangular coordinates form of A+jB, the Absolute value Z can be found from the equation Z=$\sqrt{A^2 + B^2}$. Using the P, Q and Q' scales, the calculation can be done as easily as that ordinary multiplication.

Ex. 3 Find the Absolute Value Z of 3+j7=$Z\underline{|\theta}$.

Pull the slide set the left index Q:0 against P:7, move the hairline over Q:3, read the P:7.62 under the hairline is the answer A.

Ex. 4 Find the Absolute Value Z of 52+j88.

In this case, if we perform this calculation as the example 3, then we shall see the P scale becomes "off scale". So, we must use the Q' scale to do it. Pull the slide set the right index P:10 against Q:88, move the hairline over P:52, read the Q':102.2 under the hairline is the answer A. If you do not use the Q' scale, you can multiply or divide the numbers by a simple digit such as 2, 3, or 1/2, 1/3 etc. so as to be treaded them within the range of P and Q scales.

Ex. 5 Same the Ex. 4, we can divide the numbers 52, and 88 by 2, and get 52+j88=2(26+j44). Then, we can perform the calculation as the example 3, get the Z=2×51. 1=102. 2

Find Phase Angle

The phase angle θ between the real part A and the absolute value Z of given vector which is represented by A+jB, can be solved as $\theta = tg^{-1}\frac{B}{A}$.

Ex. 6 Find θ in the Ex. 3,

Firstly, using C and D scales calculate 7/3=2.333, move the hairline over T:2.333, read θ:66.8° is the answer.

Conversion of measure of angles

Using scales θ and R_θ in "reference scales", we can convert the measure of angles, degree into radian and vice versa.

Ex. 7 Convert 45° into radians,

Move the hairline over θ:45°, read the 0.785 on R_θ scale is the answer.

i.e. 45°=0.785radian

Ex. 8 Convert 1.23 radian into degree,

Move the hairline over R_θ:1.23, read the 70.5° on θ scale is the answer.

i.e. 1.23radian=70.5°

Conversion of Coordinates

Summarizing above mentioned techniques, we can convert the coordinates of given vector of the form A±jB into the form $Z|\underline{\theta}$, and vice versa.

Ex. 9 Invert 3+j7 into the form $Z|\underline{\theta}$

As the calculating of above, we have found out the Z=7.62, and the θ = 66. 8° .

i.e. 3+j7= $7.62|\underline{66.8°}$

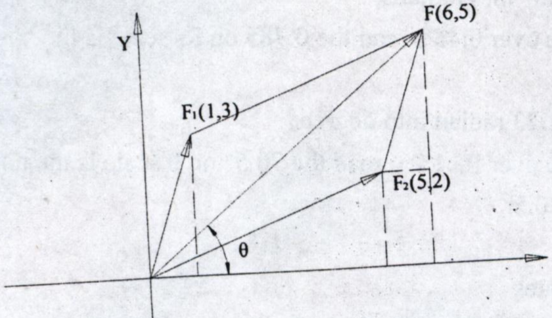
Ex. 10 Invert $5|\underline{36.9^\circ}$ into rectangular coordinates.

Using the scales θ, P and Q calculate $\sin 36.9^\circ=0.6$, $\cos 36.9^\circ=0.8$ as mentioned Ex.1, then, using C and D scales, by ordinary multiplication, we can get the real part of the vector $5\times0.8=4$, and the imaginary part $5\times0.6=3$,

i. e. $5|\underline{36.9^\circ}=4+j3$.

Find the Composition of Two Vectors

Ex. 11 Known two force F_1 and F_2 act at one point, the projections are $X_1=1$, $Y_1=3$, $X_2=5$, $Y_2=2$. find the Composition force F and the direction angle θ.



Suppose X and Y are the projections of F,

Then $X=X_1+X_2=6$

$Y=Y_1+Y_2=5$

① Using the scales C and D calculate 5/6, set C:6 against D:5, under Right index C:10 read 0.833 on D scale; ② using T and θ scales find the angle, move hairline over T:0.833 and read θ:39.8°. ③ Using P and Q scale calculate F, set Q:0 against P:5, read P:7.82 against Q:6 is F.

i.e. $F=7.82|\underline{39.8^\circ}$

Ex. 12 Known two force $F_1=5|\underline{60^\circ}$, and $F_2=9|\underline{10^\circ}$ act at one point, find the Composition force F and the direction angle θ.

Suppose X and Y are the projections of F, Then $X = 5\cos60° + 9\cos10° = 11.36$

$Y = 5\sin60° + 9\sin10° = 5.892$

Solve it as above Example get $F = 12.79\underline{|27.4°}$.

III. Usage of Scales of Hyperbolic Function G_θ

The G_θ scale for hyperbolic functions was invented by Hisashi Okura. A US patent was issued in 1937 for the G_θ scale. The system of scales for hyperbolic functions is based on the Gudermanian function gd x. The Gudermanian is defined by

$$gdx = 2tg^{-1}\left(th\frac{x}{2}\right)$$

it can also be shown that an equivalent definition is

$$gdx = \sin^{-1}(thx)$$

Although the Gudermanian looks obscure, the function has special properties that connect trigonometric functions and hyperbolic functions. The identities are:

Sh x = tg gd x

Ch x = sec gd x

Th x = sin gd x

To get hyperbolic functions, using the G_θ, T, P scales. If you set the given argument x on G_θ scale, you can get the value of Sh x on T scale, and get the value of Th x on P scale.

Find Sh x

Ex. 13 Sh0.39=(0.4),

Set hairline directly over 0.39 on G_θ scale, read T:0.4 under the hairline is the answer.

Find Th x

Ex. 14 Th 0.424=(0.4),

Set hairline directly over 0.424 on G_θ scale, read P:0.4 under the hairline is the answer.

Find Ch x

Ex. 15 Find Ch0.65 =?

Method 1

$Chx = \sqrt{1 + Sh^2 x}$, Firstly, using G_θ and T scales get Sh0.65, set hairline over G_θ:0.65, Read 0.695 on T scale is the answer of Sh0.65. Because the relationship between Q' scale and Q scale can be shown by the equation $q' = \sqrt{1 + q^2}$. So, move the hairline over Q:0.695, read the 1.218 on Q' scale is the answer.

i.e. Ch0.65 = 1.218

Method 2

Chx=1/SechX, Move hairline over G_θ:0.65, Set the left index of C scale under the hairline, against the right index of P, we get Sech0.65=0.821, using the reciprocal relation between C and CI scales can get Ch0.65=1.218 easily.

On the G_θ scale, we can use the numbers from 0.1 to 3 for calculating the hyperbolic functions, for outside of the range of 0.1 to 3, we can get the approximations number using the following table.

x<0.1			x>3		
Shx≈ x	Thx≈ x	Chx≈1	Shx≈0. 5e^x	Thx ≈ 1	Chx≈0. 5e^x

IV. Application On Electrical Problems

Ex. 16 Compute the effective value of a votage wave which contains higher harmonics, assuming effective values of its component as follows.

The fundamental wave E_{e1}=82

The 3rd harmonics E_{e3}=25

The 5th harmonics E_{e5}=12

$$E_{e0} = \sqrt{E^2_{e1} + E^2_{e3} + E^2_{e5}} = \sqrt{82^2 + 25^2 + 12^2} = 86.6$$

Set Q:0 to P:82, move thehairline to Q:25, Set Q:0 under the hairline, and then, against Q:12 we can read the 86.6 on P scale is the answer.

Ex. 17 Calculate the current in an electric circuit, which impedance is 2+j3.2 and the potential difference between its terminals is 50+j15.

$$\dot{I} = \frac{\dot{E}}{\dot{Z}} = \frac{50 + j15}{2 + j3.2}$$

Representing both numerator and donominator in a polar coordinates, we get

$$50+j15=52.2\underline{|0.29}$$

$$2+j3.2=3.77\underline{|1.011}$$

And then

$$\dot{I} = \frac{52.2}{3.77}\underline{|0.29-1.011} = 13.85\overline{|0.721}$$

If necessary, the answer can be converted into rectangular coordinates as below:

Using P and Q scale,

Sin0.721=0.661

Cos0.721=0.751

Then, multiplying on these sequences by the absolute value 13.85, we can get

$$\dot{I} = 10.4 + j9.15$$

V. About Gauge Marks on Slide Rule

On the slide rule, there are some gauge marks. These marks can make some calculation more easy.

1. π, 2π. On C and D scales. They are the ratio of circumference to the diameter of a circle.
2. c. On C scale. Area of a circle.
3. ρ°, ρ′, ρ″, on C scale. Conversion between degree and radian.