Precision Slide Rules

Jakar

Instructions for using No. 11 125mm (5") RIETZ
No. 22 125mm (5") DARMSTADT
No. 29 250mm 10") STUDENT LOG/LOG
No. 33 125mm (5") DUPLEX LOG/LOG
No. 55 250mm (10") RIETZ
No. 66 250mm (10") ELECTRO
No. 77 250mm (10") DARMSTADT
No. 88 250mm (10") COLLEGE DUPLEX
No. 99 250mm (10") DUPLEX LOG/LOG

Introduction

A Slide Rule is relatively easy to use even though it may take practice to become really familiar with it. In using the various scales you will find it helpful to work out a simple problem which you can check mentally before going on to more complicated calculations. In this way confidence and a proper understanding of the scales is quickly built up, together with an appreciation of the use which can be made of the slide rule. Make a practice of rough checking your answer mentally—ask yourself 'Does it look right?' and in this way you will come to rely a great deal on your slide rule.

If treated with reasonable care and attention your slide rule will give you many years of good service.

All slide rules consist of three parts: the stock or fixed section; the centre slide, which moves between the fixed parts of the stock; and the transparent cursor with a hair-line at its centre.

The engraved scales are coloured either in black or in red. Black is used for scales whose numbers increase in magnitude from left to right. Red is used for scales whose numbers increase in magnitude from right to left.

This instruction booklet covers the Jakar range of precision slide rules. The scales applicable to a particular rule are listed under the slide rule reference, for example No. 33 Duplex log/log, and this enables the sections in the instruction booklet applicable to, say, this rule to be identified. From then on it will be straight forward to work through the appropriate sections in the booklet.

Description of Scales

Slide Rule No. 11 Rietz

K	=	x^3	cube scale
A	=	x^2	scale of squares
B	=	x^2	scale of squares
C1	=	$\frac{1}{x}$	reciprocal C scale
C	=	x	basic scale of the slide 1 to 10
D	=	x	basic scale of the lower part 1 to 10
L	=	lg.x	mantissa scale for determining common logarithms

Reverse side

S	=	∡ sin 0·1x (cos)	sine (and cosine) scale
ST	=	∡ arc 0·01x	sine and tangent scale
T	=	∡ tan 0·1x (cot)	tangent (and cotangent) scale

With additional mm scale.

Description of Scales

Slide Rule No. 22 — Darmstadt

LL2	=	$e^{0 \cdot 1x}$	log/log scale, range 1·105 to e
LL3	=	e^x	log/log scale, range e to 20,000
A	=	x^2	scale of squares
B	=	x^2	scale of squares
C1	=	$\frac{1}{x}$	reciprocal C scale
C	=	x	basic scale of the slide 1 to 10
D	=	x	basic scale of the lower part 1 to 10
K	=	x^3	cube scale
LL1	=	$e^{00 \cdot 1x}$	log/log scale, range 1·01 to 1·105

Reverse Side

P	=	$\sqrt{1-x^2}$	Pythagorean scale
T	=	∡ tan 0·1x (cot)	tangent (and cotangent) scale
L	=	lg.x	mantissa scale for determining common logarithms

S = ∡ sin 0·1x (cos) sine (and cosine) scale

With additional mm scale

Description of Scales

Slide Rule No. 29 — Student log/log

L	=	lg.x	mantissa scale for determining common logarithms
K	=	x^3	cube scale
A	=	x^2	scale of squares
B	=	x^2	scale of squares
C1	=	$\frac{1}{x}$	reciprocal C scale
C	=	x	basic scale of the slide 1 to 10
D	=	x	basic scale of the lower part 1 to 10
S	=	∡ sin 0·1x (cos) sine (and cosine) scale	
ST	=	∡ arc 0·01x sine and tangent scale	
T	=	∡ tan 0·1x (cot) tangent (and cotangent) scale	

Reverse Side

S	=	∡ sin 0·1x (cos) sine (and cosine) scale	
LL1	=	$e^{0 \cdot 01x}$	log/log scale, range 1·01 to 1·105
LL2	=	$e^{0 \cdot 1x}$	log/log scale, range 1·1 to 3·0
LL3	=	e^{x}	log/log scale, range 2·5 to 50,000

With additional inch and mm scale.

Description of Scales

Slide Rule No. 33 — Duplex log/log

LL−1	=	$e^{-0 \cdot 01x}$	log/log scale, range 0·99 to 0·905
LL−2	=	$e^{-0 \cdot 1x}$	log/log scale, range 0·905 to 0·37
LL−3	=	e^{-x}	log/log scale, range 0·37 to 0·00005
DF	=	πx	basic scale folded, beginning with π
CF	=	πx	basic scale folded, beginning with π
C1F	=	$\frac{1}{\pi x}$	reciprocal CF scale
C1	=	$\frac{1}{x}$	reciprocal C scale
C	=	x	basic scale of the slide 1 to 10

D	=	x	basic scale of the slide 1 to 10
LL3	=	e^{x}	log/log scale, range e to 20,000
LL2	=	$e^{0{\cdot}1x}$	log/log scale, range 1·105 to e
LL–1	=	$e^{-0{\cdot}01x}$	log/log scale, range 1·01 to 1·105

Reverse Side

LL–0	=	$e^{-0{\cdot}001x}$	log/log scale, range 0·999 to 0·990
K	=	x^3	cube scale
A	=	x^2	scale of squares
B	=	x^2	scale of squares
T	=	∡ tan 0·1x (cot)	tangent (and cotangent) scale
S	=	∡ sin 0·1x (cos)	sine (and cosine) scale
C	=	x	basic scale of the slide 1 to 10
D	=	x	basic scale of the lower part 1 to 10
P	=	$\sqrt{1-x^2}$	Pythagorean scale
L	=	lg.x	mantissa scale for determining common logarithms
LL0	=	$e^{0{\cdot}001x}$	log/log scale, range 1·001 to 1·01

Description of Scale

Slide Rule No. 55 Rietz

K	=	x^3	cube scale
A	=	x^2	scale of squares
B	=	x^2	scale of squares
C1	=	$\frac{1}{x}$	reciprocal C scale
C	=	x	basic scale of the slide 1 to 10
D	=	x	basic scale of the lower part 1 to 10
L	=	lg.x	mantissa scale for determining common logarithms

Reverse Side

S	=	∡ sin 0·1x (cos)	sine (and cosine) scale
ST	=	∡ arc 0·01x	sine and tangent scale
T	=	∡ tan 0·1x (cot)	tangent (and cotangent) scale

With additional mm scale

Description of Scales

Slide Rule No. 66 — Electro

K	=	x^3	cube scale
E	=	voltage drop, dynamo/motor efficiency scale	
A	=	x^2	scale of squares
B	=	x^2	scale of squares
C1	=	$\frac{1}{x}$	basic scale of the slide 1 to 10
D	=	x	basic scale of the lower part 1 to 10
LL3	=	e^x	log/log scale, range 2·5 to 50,000
LL2	=	$e^{0 \cdot 1x}$	log/log scale, range 1·1 to 3·0
L	=	lg.x	mantissa scale for determining common logarithms

Reverse Side

S	=	$\measuredangle$ sin 0·1 (cos) sine (and cosine) scale
ST	=	$\measuredangle$ arc 0·01x sine and tangent scale
T	=	$\measuredangle$ tan 0·1x (cot) tangent (and cotangent) scale

With additional mm scale.

Description of Scales

Slide Rule No. 77 — Darmstadt

LL1	=	$e^{0 \cdot 01x}$	log/log scale, range 1·01 to 1·11
LL2	=	$e^{0 \cdot 1x}$	log/log scale, range 1·1 to 3·0
LL3	=	e^x	log/log scale, range 2·5 to 50,000
A	=	x^2	scale of squares
B	=	x^2	scale of squares
B1	=	$\frac{1}{x^2}$	reciprocal scale of B
C1	=	$\frac{1}{x}$	reciprocal C scale
C	=	x	basic scale of the slide 1 to 10
D	=	x	basic scale of the lower part 1 to 10
P	=	$\sqrt{1-x^2}$	Pythagorean scale
K	=	x^3	cube scale
LL0	=	$e^{0 \cdot 001x}$	log/log scale, range 1·001 to 1·01

Reverse Side

T2	=	∡ tan 0·1x (cot) tangent (and cotangent) scale	
T	=	∡ tan 0·1x (cot) tangent (and cotangent) scale	
L	=	lg.x	mantissa scale for determining common logarithms
S	=	∡ sin 0·1x (cos) sine (and cosine) scale	

With additional mm scale

Description of Scales

Slide Rule No. 88 — College Duplex

LL1	=	$e^{0\cdot01x}$	log/log scale, range 1·010 to 1·11
LL2	=	$e^{0\cdot1x}$	log/log scale, range 1·1 to 3·0
LL3	=	e^x	log/log scale, range 2·5 to 50,000
DF	=	πx	basic scale folded, beginning with π
CF	=	πx	basic scale folded, beginning with π
C1F	=	$\frac{1}{\pi x}$	reciprocal CF scale
C1	=	$\frac{1}{x}$	reciprocal C scale
C	=	x	basic scale of the slide 1 to 10
D	=	x	basic scale of the lower part 1 to 10
L	=	lg.x	mantissa scale for determining common logarithms
K	=	x^3	cube scale

Reverse Side

T1	=	∡ tan 0·1x (cot) tangent (and cotangent) scale	
T2	=	∡ tan 0·1x (cot) tangent (and cotangent) scale	
A	=	x^2	scale of squares
B	=	x^2	scale of squares
B1	=	$\frac{1}{x^2}$	reciprocal scale of B
C1	=	$\frac{1}{x}$	reciprocal C scale
C	=	x	basic scale of the slide 1 to 10
D	=	x	basic scale of the lower part 1 to 10
P	=	$\sqrt{1-x^2}$	Pythagorean scale

S	=	∡ sin 0·1x (cos) sine (and cosine) scale
ST	=	∡ arc 0·01x sine and tangent scale

Description of Scales

Slide Rule No. 99 Duplex log/log

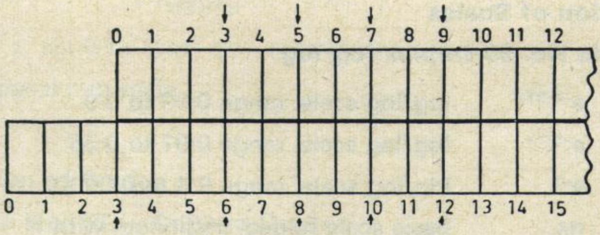
LL–1	=	$e^{-0{\cdot}01x}$	log/log scale, range 0·99 to 0·9
LL–2	=	$e^{-0{\cdot}1x}$	log/log scale, range 0·91 to 0·35
LL–3	=	e^{-x}	log/log scale, range 0·4 to 0·00002
DF	=	πx	basic scale folded, beginning with π
CF	=	πx	basic scale folded, beginning with π
C1F	=	$\frac{1}{\pi x}$	reciprocal CF scale
C1	=	$\frac{1}{x}$	reciprocal C scale
C	=	x	basic scale of the slide 1 to 10
D	=	x	basic scale of the lower part 1 to 10
LL3	=	e^{x}	log/log scale, range 2·5 to 50,000
LL2	=	$e^{0{\cdot}1x}$	log/log scale, range 1·1 to 3·0
LL1	=	$e^{0{\cdot}01x}$	log/log scale, range 1·01 to 1·11

Reverse Side

LL–0	=	$e^{-0{\cdot}001x}$	log/log scale, range 0·999 to 0·99
K	=	x^3	cube scale
A	=	x^2	scale of squares
B	=	x^2	scale of squares
ST	=	∡ arc 0·01x	sine and tangent scale
T	=	∡ tan 0·1x (cot)	tangent (and cotangent) scale
S	=	∡ sin 0·1x (cos)	(and cosine) scale
C	=	x	basic scale of the slide 1 to 10
D	=	x	basic scale of the lower part 1 to 10
P	=	$\sqrt{1-x^2}$	Pythagorean scale
L	=	lg.x	mantissa scale for determining common logarithms
LL0	=	$e^{0{\cdot}001x}$	log/log scale, range 1·001 to 1·01

THE PRINCIPLE OF THE SLIDE RULE

When using a Slide Rule, calculations are made by representing numbers by distances on the rule. This fundamental principle may be illustrated by the figure below:



Two scales divided in equal distances (inches or cm) are placed next to one another. On these scales the number 3 is represented by the distance between the digits 0 and 3. If it is desired to add any number x to 3, one scale is moved until its 0 coincides with the 3 on the other scale as shown. Under each number x on the upper scale is x+3 on the lower scale. Conversely, above any number x on the lower scale is x−3 on the upper scale. With one scale fixed and the other movable, it is thus possible to perform every addition and subtraction, since any setting of the two scales gives a series of sums and differences.

The practical value of this graphical method of addition and subtraction is small, since these processes can usually be performed easily by other means. A graphical method of multiplication and division is very much more useful and this can be achieved by applying the logarithmic principle. The use of logarithms reduces the tasks of multiplication and division to those of addition and subtraction. Consequently, the scale markings on a Slide Rule are made so that the distances depend on the logarithm of the numbers, and this enables products and quotients to be found by a simple graphical operation.

THE NORMAL SCALES

The scales A and B on the upper part, and the scales C and D on the lower part of the Slide Rule are called the Normal Scales, and are sufficient for the great majority of practical calculations. The scales C and D are particularly useful as they give more exact results than the shorter upper scales A and B.

THE DIVISIONS ON THE NORMAL SCALES

On an ordinary ruler, markings representing centimetres are numbered, while their sub-divisions (the millimetres) are indicated by lines alone. Any further sub-divisions (such as tenths of millimetres) can only be estimated. On a Slide Rule, because of the logarithmic principle involved, the separation of the markings becomes less towards the right-hand side. For the sake of clarity, some of the sub-divisions on the right-hand side must be omitted, and estimation is therefore necessary.

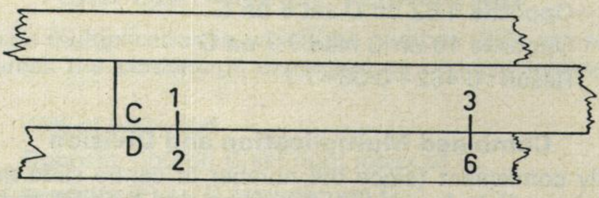
The section 1-2 of scales C and D is sub-divided into 10 principal distances, which are marked 1·1, 1·2 up to 1·9 and 2. Each of these sub-divisions is again sub-divided into 10 distances (in case of the 5-in. Pocket Slide Rule, however, only into 5 distances). They are read 1·01, 1·02, up to 1·99 and 2·00 (in case of the 5-in. model 1·02, 1·04 up to 1·98 and 2·00).

The section 2-5 is also sub-divided into 10 principal distances such as 2·10, 2·20 up to 4·90 and 5·00. The sub-divisions of these are in fifths and are read 2·02, 2·04, 2·06 up to 5·00 (in case of the 5-in. Slide Rule the sub-divisions are in halves, 2·05, 2·10, 2·15 up to 5·00). In the last section 5-10 the sub-divisions progress by twentieths, 5·05, 5·10, 5·15 up to 9·95 and 10·00. (In case of the 5-in. model the sub-divisions are in tenths, 5·10, 5·20, 5·30 up to 9·90 and 10·00.)

MULTIPLICATION

For all computations the lower scales C and D should be used as they give more exact results than the shorter upper scales A and B.
Multiplication: 2×3 (see figure)

Set the 1 on the scale C (on the centre slide) above the number 2 on the scale D. Move the cursor centre line into position above the number 3 on C, and read the result on D=6. This process is illustrated below:



Example: Multiply 14×2
Opposite 1·4 on D set 1 on C
Opposite 2 on C read 2·8 on D
Result: 14×2=28

Note that the position of the decimal point is disregarded in this operation. In general, it is possible only to obtain the significant figures, and not the position of the decimal point from a Slide Rule calculation. An approximate mental calculation is necessary to give the correct position of the point.

It often occurs that with the 1 on scale C above X on D, the centre slide projects too far to the right. In this case the slide is removed to the left until the 10 on C is above X on D. The result is then read as before.

Example: Multiply 7·7×0·06

Opposite 7·7 on D set 10 on C

Opposite 6 on C read 4·62

Result: 7·7×0·6=0·462

CONTINUOUS MULTIPLICATION

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

Example: Multiply 1·5×3·2×8=38·4

Opposite 15 on D set left index of C,

opposite 32 on C set the hair-line of the cursor,

opposite the hair-line set right index of C,

opposite 8 on C read answer 38·4 on D.

You need not read the intermediate answer 1·5×3·2=4·8

Division

This operation is the inverse of multiplication.

Example: (a) Divide 28 by 2

Opposite 2·8 on D set 2 on C

Opposite 1 on C read 1·4 on D

Result 28÷2=14

(b) Divide 0·462 by 0·06

Opposite 4·62 on D set 6 on C

Opposite 10 on C read 7·7 on D

Result: 0·462÷0·06=7·7

Combined Multiplication and Division

It is usually convenient (since the number of centre slide movements will be minimised) to begin with a division and then let multiplication and division alternate. The intermediate results need not be read.

Example: Calculate $\frac{3\times4\times7}{2\times5}$

Opposite 3 on D set 2 on C

Opposite 4 on C set cursor centre line

Opposite cursor centre line set 5 on C

Opposite 7 on C read 8·4 on D

Result: $\frac{3\times4\times7}{2\times5}=8{\cdot}4$

SQUARES AND SQUARE ROOTS

Whereas you have on scales C and D one logarithmic distance 1-10, you have on scales A and B over the same length two such distances, 1-10 and 1-100. Hence, above any number X on D is its square, X^2 on A.

Example: (a) Find 25^2

Opposite 2·5 on D set cursor centre line

Opposite 2·5 on D read 6·25 on A

Result: $25^2=625$

(b) Find $0{\cdot}6^2$

Opposite 6 on D set cursor centre line

Opposite 6 on D read 36 on A

Result: $0{\cdot}6^2=0{\cdot}36$

Conversely, opposite any number on A, read its square root on D. Use the LEFT half on A if the number has an ODD number of digits, such as 1, 3, 5. Use the RIGHT half of A if the number has an EVEN number of digits, 0, 2, 4 etc., thus

Opposite 4·58 on A (left) read 2·14 on D,

Opposite 56·7 on A (right) read 7·53 on D.

Example: (a) Find $\sqrt{45{\cdot}8}$

Opposite 45·8 on A set cursor centre line

Opposite 45·8 on A read 6·77 on D

Result: $\sqrt{45{\cdot}8}=6{\cdot}77$

CALCULATIONS OF PERCENTAGE

This is a mere multiplication in which the number 100% represents one factor whereas the percentage expressed as decimal fractions is the other one.

Example: 70% of 650=455

Opposite 650 on D set right index of C,

opposite 70 on C read 455 on D

With the same setting of the slide one can read all other percentages of 650, such as 80%=520, 60%=390 etc. One may also use the upper scales A and B for this calculation. However, scales C and D should always be preferred as they are wider and therefore more exact.

THE RECIPROCAL SCALE CI

The scale CI is to be found on Slide Rules in the middle of the slide and when used with the normal scales C and D, simplifies many calculations. CI is the inverse of C and D and runs from 1 to 10 in a right to left direction. Its scale markings are in red.

For any number X on scale C, above it on CI is its reciprocal, 1/X

Example: Find 1/2·9

Opposite 2·9 on C set cursor centre line

Opposite 2·9 on C read 3·45 on CI

Result: 1/2·9=0·345

The CI Scale also permits two successive multiplications to be made with a single setting of the slide.

Example: Multiply 2×3×4

Opposite 2 on D set cursor centre line

Opposite 2 on D set 3 on CI

Opposite 4 on C read 2·4 on D

Result: 2×3×4=24

CUBE AND CUBE ROOTS

The scale covers three logarithmic distances and runs from 1 to 1,000. For any number X on scale D, the corresponding position on K gives X^3.

Example: Find $4{\cdot}2^3$

Opposite 4·2 on D set cursor centre line

Opposite 4·2 on D read 74 on K

Result: $4{\cdot}2^3=74$

Conversely, opposite a number on K, read its cube root on D. Use the right third of the scale if the number of digits in the sum is a multiple of 3(−3, 0, 3, 6 etc.) ; use the centre third if the number of digits is one less than a multiple of 3(−1, 2, 5, 8 etc.) ; use the left third if the number of digits is two less than a multiple of 3(−2, 1, 4, 7 etc.).

Examples: Opposite 2 on K (left) read 1·26 on D,

Opposite 64 on K (middle) read 4 on D,

Opposite 125 on K (right) read 5 on D.

THE LOGARITHMIC SCALE

The Scale L (Logarithms to base 10)

The logarithm (log) to the base 10 of a number has two parts, the characteristic and the decimal fraction (or mantissa). The scale L enables the decimal fraction to be found for any number, and the characteristic is found in the usual way. For a number X on D, the corresponding position on L gives the decimal fraction.

Example: (a) Find $\log_{10}23{\cdot}16$

Opposite 2·316 on D set cursor centre line

Opposite 2·316 on D read 0·365 on L

Result: $\log_{10}23{\cdot}16=1{\cdot}365$

(b) Find $\log_{10}0{\cdot}58$

Opposite 5·8 on D set cursor centre line

Opposite 5·8 on D read 0·763 on L

Result: $\log_{10}0{\cdot}58=-1+0{\cdot}763$

THE TRIGONOMETRIC SCALES

The scales S(sine) T and T_2(tangent) and ST(sine and tangent of small angles) are used cheifly with C and D to find trigonometric functions. Conversely, if the trigonometric functions are given, the corresponding angles may be found.

THE SCALE S
(Sine Ratios)

The scale S provides a table of values of sine *a*. The scale runs from left to right and covers the range from approximately $5\frac{1}{2}°$ to 90°. For any angle on S the corresponding position on C or D gives sin *a*.

Example: Find sin 32° 30′

Opposite 32° 30′ on S set cursor centre line

Opposite 32° 30′ on S read 5·37 on C or D

Result: sin 32° 30′=0·537

Examples: sin 9° 15′=0·161, sin 39·5°=0·636,
sin 48° 40′=0·751

THE SCALE T

This scale covers the range from approximately $5\frac{1}{2}°$ to 45°. For any angle *a* on T the corresponding position on C or D gives tan *a*.

Example: Find tan 22°

Opposite 22° on T set cursor centre line

Opposite 22° on T read 4·04 on C or D

Result: tan 22°=0·404

THE SCALE T_2

This scale covers the range from 45° to $84\frac{1}{2}°$ and is used in the same way as the scale T.

Example: Find tan 52°

Opposite 52° on T_2 set cursor centre line

Opposite 52° on T_2 read 1·28 on D

Result: tan 52°=1·28

THE SMALL ANGLE SCALE ST (Sine-tangent)

For small angles (below about $5\frac{1}{2}°$) the relation: sin $a \approx$ tan $a \approx$ arc a is valid (where arc a is the radian measure of the angle). The scale ST covers the range from $\frac{1}{2}°$ to approximately $5\frac{1}{2}°$ and is used with scales C and D to find sin a, tan a, and arc a for these angles.

For any angle a on ST, the corresponding position on C or D gives sin a, tan a, and arc a.

Example: Find sin 3° 30′
Opposite 3° 30′ on ST set cursor centre line
Opposite 30° 30′ on ST read 6·11 on C or D
Result: sin 30° 30′≈0·0611
(Also tan 3° 30′≈arc 3° 30′≈0·0611)

The scale ST may also be used to calculate cosine and cotangent ratios for angles above $84\frac{1}{2}°$ (using the relations: cos a=sin [90−a] and cot a=tan [90−a]).

CALCULATION OF AREA OF CIRCLE

The cursor is engraved with two short lines on its underside, either side of the cursor hair-line, one at top left and the other at lower right.

The area of a circle can read directly for a given diameter.

By placing the cursor hair-line over any number on scale D, indicating the diameter of a circle, the area of this circle is found on scale A under the left-hand red line. Conversely, if the area is known, the diameter is found by placing the hair-line over the area on scale A, and reading the diameter on scale D under the right-hand red line.

Diameter of circle—2 in.—place cursor centre line over 2 on scale D and read area on scale A under left-hand line—answer 3·14(π) sq. in.

Area of circle—13 sq. in.—place cursor centre line over 13 on scale A and read diameter on scale D right-hand line—answer 4·07.

THE SCALE P
(Pythagorean Scale)

In many problems it is necessary to calculate the quantity $\sqrt{1-X^2}$. The scale P, which facilitates this operation, runs from 0·1 to 1 in a right to left direction and its markings are in red. For any number X on D the corresponding position on P gives $\sqrt{1-X^2}$.

Example: (a) Find $\sqrt{1-0{\cdot}41^2}$
Opposite 4·1 on D set cursor centre line
Opposite 4·1 on D read 0·912 on P
Result: $\sqrt{1-0{\cdot}41^2}=0{\cdot}912$

(b) If cos a=0·74, find sin a

Opposite 7·4 on D set cursor centre line

Opposite 7·4 on D read 0·673 on P

Result: $\sqrt{1-0 \cdot 74^2}=\sin a=0 \cdot 673$

THE SCALE BI

The scale BI, marked on the slide beneath the scale B, is the inverse of B. It runs from 1 to 100 in a right to left direction. For any number X on scale C, above it on BI is $1/X^2$.

Example: Find $1/8 \cdot 1^2$

Opposite 8·1 on C set cursor centre line

Opposite 8·1 on C read 1·52 on BI

Result: $1/8 \cdot 1^2=0 \cdot 0152$

Conversely, for any number X on the scale BI, below it on C is $1/\sqrt{X}$. If X does not lie in the interval 1 to 100, it must be brought into the range by multiplication or division by a power of 100.

THE SCALES CF AND DF
("Folded" Scales)

These scales are identical in construction to the scales C and D, except that the index (1) of each is near the middle of each scale. CF and DF are "folded" scales beginning and ending at points other than 1.

The use of CF and DF at the appropriate stage of a calculation will minimise the amount of slide movement required. For example, if in multiplication on scales C and D, it becomes necessary to reset the slide from 1 on C to 10 on C, this can be avoided by setting the number on CF and reading the result on DF.

Example: Multiply 2·91×4

Opposite 2·91 on D set 1 on C

Opposite 4 on CF set cursor centre line

Opposite 4 on CF read 1·164 on DF

Result: 2·91×4=11·64

THE SCALE CIF

This scale is the inverse of the scale CF, runs from right left on the slide. It is used in conjunction with the scales CF and DF in the same way that the scale CI is used with C and D.

Example: Multiply 2·56×15·3×1·2×2·5

Opposite 1·53 on D set 2·56 on CI

Opposite 1·2 on CF set cursor centre line
Opposite cursor centre line set 2·5 on CIF
Opposite 1 on CF read 1·173 on DF
Result: $2{\cdot}56 \times 15{\cdot}3 \times 1{\cdot}2 \times 2{\cdot}5 = 117{\cdot}3$

Note: The scales CF and DF are "folded" by π. Consequently, it is possible to multiply any number by π without slide movement.

Example: Multiply $2{\cdot}5 \times \pi$
Opposite 2·5 on D set cursor centre line
Opposite 2·5 on D read 7·86 on DF
Result: $2{\cdot}5 \times \pi = 7{\cdot}86$

THE EXPONENTIAL SCALES

The Scales LL (Log/Log Scales)

These consist of the following scales: LL_0, LL_1, LL_2, LL_3, for positive exponents, covering the range 1·001 to 50,000 from left to right.

LL_{-0}, LL_{-1}, LL_{-2}, LL_{-3}, for negative exponents, covering the range 0·00002 to 0·999 from right to left and marked in red.

Note: On these scales the decimal point is fixed so that, for example, 1·07 represents only 1·07 and not 10·7, 107, etc.

The scales LL are based on the normal scale D. For any number X on D, the value of e^x is given on LL_3,$e^{0\cdot1x}$, on LL_2,$e^{0\cdot01x}$, on LL_1, and so on. The negative exponent scales are the reciprocal scales of the positive expondent scales. Thus for any number X on D, scale LL_{-3} gives e^{-x}, LL_{-2} gives $e^{-0\cdot1x}$, and so on.

Operations Using the Scales LL

The provision of Log/Log scales makes it possible to perform many sophisticated mathematical operations on the Slide Rule.

Powers of 10: For any number X on LL_1, the corresponding position on LL_2 gives X^{10} and LL_3 gives X^{100}.

Example: Find $(1{\cdot}0471)^{10}$ and $(1{\cdot}0471)^{100}$
Opposite 1·0471 on LL_1 set cursor centre line
Opposite 1·0471 on LL_1 read 1·585 on LL_2
Opposite 1·0471 on LL_1 read 100 on LL_3
Result: $(1{\cdot}0471)^{10} = 1{\cdot}585$ and $(1{\cdot}0471)^{100}$

The process may be reversed to find the corresponding roots.

Hyperbolic Functions

For any number X on D, the values of e^x and e^{-x} can be found from the LL scales. Half the sum (or difference) gives cosh X or sinh X.

Example: Find sinh 0·434

Opposite 4·34 on D set cursor centre line

Opposite 4·34 on D read 1·554 on LL_2

Opposite 4·34 on D read 0·648 on LL_{-2}

Result: sinh 0·434=$\frac{1}{2}$(1·544–0·648)=0·488

Powers of e

These are found by setting the exponent on the scale D. The power of e is then in the corresponding position on the appropriate LL scale.

Example: (a) Find e^2

Opposite 2 on D set cursor centre line

Opposite 2 on D read 7·39 on LL_3

Result: $e^2=7{\cdot}39$

(b) Find $\sqrt{e}=e^{0{\cdot}5}$

Opposite 5 on D set cursor centre line

Opposite 5 on D read 1·648 on LL_3

Result: $\sqrt{e}=1{\cdot}648$

Natural Logarithms (Logs to base e)

These are found by reversing the previous process. For any number X on an LL scale the corresponding position on D gives $\log_e X$. The location of the decimal point is as follows:

For scales LL_3 and LL_{-3}, the values on D are used directly.

For scales LL_2 and LL_{-2}, the values on D are divided by 10.

For scales LL_1 and LL $_1$, the values on D are divided by 100.

For scales LL_0 and LL_{-0}, the values on D are divided by 1,000.

The sign of the logarithm is positive if X is on a positive exponent scale, negative if X is on a negative exponent scale.

Example: (a) Find $\log_e 3{\cdot}4$

Opposite 3·4 on LL_3 set cursor centre line

Opposite 3·4 on LL_3 read 1·224

(b) Find $\log_e 0{\cdot}97$

Opposite 0·97 on LL_{-1} set cursor centre line

Opposite 0·97 on LL_{-1} read 3·05 on D

Result: $\log_e 0{\cdot}97=-0{\cdot}0305$

Powers of any desired number: Powers of X, that is X^n, are found by setting the 1 (or 10) mark on scale C above X on the appropriate LL scale. The cursor is then moved to n on C, and the value of X^n is read from the corresponding LL scale. (This procedure is equivalent to finding $\log_e X$, multiplying by n, and finding the anti-logarithm).

Example: Find $2{\cdot}5^{3{\cdot}5}$
Opposite 2·5 on LL_2 set 10 on C
Opposite 3·5 on C read 24·7 on LL_3
Result: $2{\cdot}5^{3{\cdot}5}$ 24·7

Roots of any desired number: Since $\sqrt[n]{X}=X^{1/n}$, the process is similar to that described above.

Example: Find $\sqrt[3{\cdot}5]{2{\cdot}5}$
Opposite 2·5 on LL_2 set 3·5 on C
Opposite 1 on C read 1·299 on LL_2
Result: $\sqrt[3{\cdot}5]{2{\cdot}5}=1{\cdot}299$

Logarithms to any desired base: To find $\log_n X$, the base n is located on the appropriate LL scale, and the 1 (or 10) mark on C is set at this point. Values of $\log_n X$ may then be obtained by finding X on the LL scales and reading the corresponding value on C.

Example: Find $\log_2 8$; $\log_2 22$; $\log_2 200$
Opposite 2 on LL_2 set 10 on C
Opposite 8 on LL_3 read 3 on C
Opposite 22 on LL_3 read 4·46 on C
Opposite 200 on LL_3 read 7·64 on C
Result: $\log_2 8=3$; $\log_2 22=4{\cdot}46$; $\log_2 200=7{\cdot}64$

THE SCALE MARKS P°, P′ and P″

Since 1 radian=57·3°, an angle ∝ given in degrees may be converted to radians by dividing *a*° by 57·3. Conversely, if ∝ is given in radians, the equivalent value in degrees is given by multiplying arc *a* by 57·3. To facilitate these operations this value is marked as *p*° on scales C and D.

Example: Convert 20° to radians
Opposite 2·0 on D set *p*° on C
Opposite 10 on C read 3·49 on D
Result: 20°=0·349 radians

Similarly, since 1 radian=57·3×60′, an angle *a* given in minutes may be converted to radians by dividing *a*′ by 3,438 (and vice versa). This value is marked as *p* on scales C and D.

By the same process, since 1 radian=57·3×3,600″, an angle ∝ given in seconds may be converted to radians by dividing *a*″ by 206, 280 (and vice versa). This value is marked as *p*′ on the Slide Rules on scales C and D.

The use of the scale marks in evaluating small angles is particularly valuable on the No. 33 Slide Rule, which has no ST scale, and for angles less than $\frac{1}{2}°$. Since arc $a \approx \sin a \approx \tan a$, finding arc a using $p°$, p' or p'' gives sin a and tan a for angles less than $5\frac{1}{2}°$.

Example: Find tan 3° 30′ using scale mark p

Convert 3° 30′ to 210′

Opposite 2·1 on D set p' on C

Opposite 10 on C read 6·11 on D

Results: Arc 3° 30′ ≈ tan 3° 30′ ≈ 0·0611

DYNAMO/MOTOR SCALE

The upper scale E marked dynamo and motor is used for calculating the efficiency, the output or the horse-power of dynamos and motors.

Efficiency of Dynamos

Determine the efficiency of a dynamo using 120 horse-power with an output of 80 kW. Using the scales A and B divide 80 by 120 and read the answer 90·5% by means of the indicator on the slide.

Corresponding values of horse-power and output in kW can be found by setting the indicator on the slide on any fixed efficiency.
Example: Efficiency 85% gives h.p./kW: 20/12·5 30/18·8 40/25 80/50

Efficiency of Motors

Determine the efficiency of a motor of 35 h.p. with an input of 30kW. Divide the input by the h.p. using the scales A and B and read the answer 86% on the motor scale at the indicator.

Note: There exists a difference between one horse-power in British measure (1 h.p.=550 ft/lb per sec.=746 watts) and one horse-power in the metric system (1 h.p.=75 kg=736 watts) the indicator to the scale dynamo and motor and the corresponding mark on the Slide Rule are based upon the metric system of 1 h.p.=736 watts.

Conversion of kW to h.p.

The interval between the centre hair-line and the upper right line represents the factor for converting kW to h.p. and vice-versa referred to readings along scale A.

For instance: When the centre line is over 20 kW the 27·1 h.p. is found under the upper right line of the cursor.

Inversely, by setting the h.p. line to 7 we read 5·15 kW under the centre hair-line.

Voltage Scale

This scale is used to calculate voltage drop, current strength, length or cross-section of a conductor, when three of these factors are known.

The voltage drop in a copper wire conductor with direct current or induction free, alternating current is

$e = \frac{JL}{cq}$ where e = loss of potential in volts

J = current strength in amps

L = length of conductor in metres

q = area of copper section in square millimetres

c = 28·7 specific conductivity of copper 0·5

Example: Find the voltage drop for a copper conductor of 10 sq. mm section and 74 m in length, current strength of 12 amps.

Using the A and B scales, multiply 12 by 75, divide the result by 10 and read the answer 3·13 volts at the end of the slide index on the voltage scale.

If this voltage drop is too high, the cross-section can be found for a loss of say, 2 volts, by leaving the cursor in the position arrived at by multiplying 12 by 75 and moving the centre slide so that the left-hand index comes in line with 2 on the voltage scale and the corresponding area read off the B scale under the cursor hair-line 15·7, that is a conductor of 16 mm^2 will be used.

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