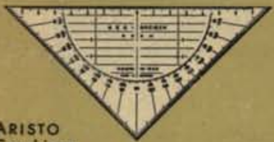
ARISTO



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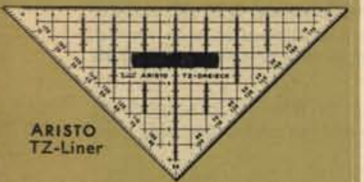

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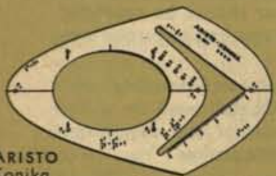

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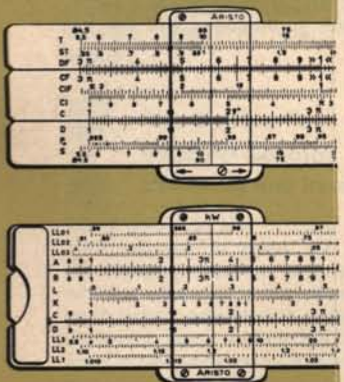

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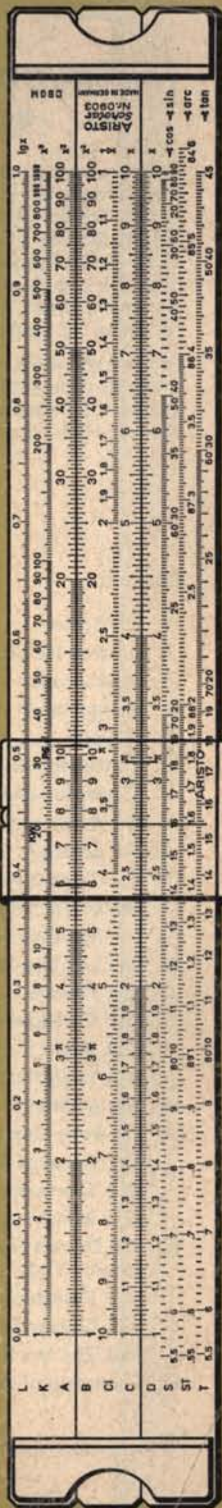
INSTRUCTIONS FOR USE

ARISTO SCHOLAR

0903 · 0903 LL
0903 VS · 0903 VS-2

E



THE ARISTO SCHOLAR SLIDE RULE

0903 0903 LL 0903 VS 0903 VS-2

These instructions are intended as a brief introduction into the fundamentals of slide rule computation for users of the ARISTO Scholar, ARISTO Scholar LL, ARISTO Scholar VS and ARISTO Scholar VS-2. In the given examples the principles and manipulations involved are presented concisely, accompanied by many explanatory diagrams arranged in systematic order, so that this pamphlet may serve as a collection of operational formulas for easy reference.

For an exhaustive treatise on the principles and practice of slide rule computations the reader may refer to Dr. Richard Stender's handbook "The Modern Slide Rule", Publishers Cleaver-Hume Press Ltd., London.

Contents

1. The Scales

The front face of the slide rule is identical in all three ARISTO Scholar models. Millimeter and Inch Scales on Back of Body.

L	Mantissa Scale	lg x	Upper panel of body
K	Cube Scale	x^3	
A	Scale of Squares	x^2	
B	Scale of Squares	x^2	On the Slide
CI	Reciprocal Scale (Inverted Scale)	1/x	
C	Fundamental Scale	x	

D	Fundamental Scale	x	Lower panel of body
S	Scale of Sines 5.5° to 90° and Cosines 0° to 84.5°, counter-clockwise with red numerals	∢ sin, ∢ cos	
ST	Scale of Small Angles .55° to 6° and Cofunctions 84° to 89.45°, counter-clockwise with red numerals	∢ arc	
T	Scale of Tangents 5.5° to 45°; 45° to 84.5°, counter-clockwise with red numerals. Available for Cotangents.	∢ tan	

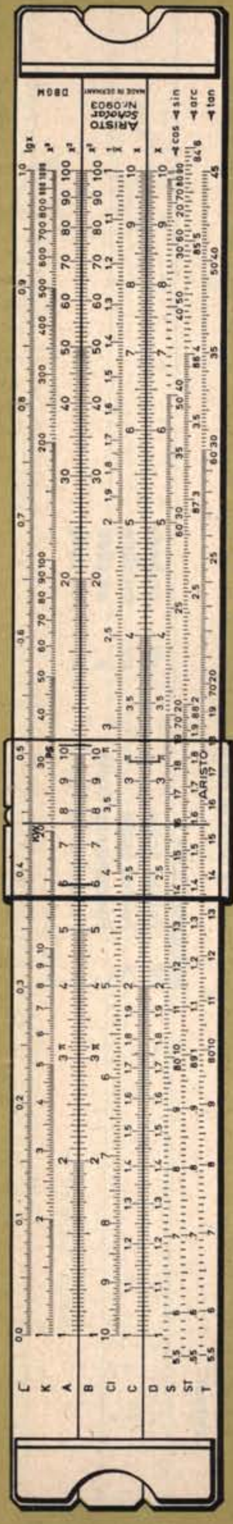


Fig. 1 Front face of 0903 · 0903 LL · 0903 VS · 0903 VS-2

The rear face of the ARISTO Scholar VS is reserved for the scale combination C, D and CF, DF, with no other scales intervening to divert the eye. The simplicity of this layout will be appreciated by beginners as well as practitioners, and, where problems are exclusively concerned with multiplication, division, proportion and the like, this side of the rule recommends itself by its convenience and clarity. With ARISTO Scholar model VS the cursor must be changed over from the front to the back of the rule. In contrast, the ARISTO Scholar VS-2 has a double-sided cursor.

Millimeter Scale			
DF	Folded Scale	πx	on body
CF	Folded Scale	πx	on slide
C	Fundamental Scale	x	on slide
D	Fundamental Scale	x	on body
Inch Scale			

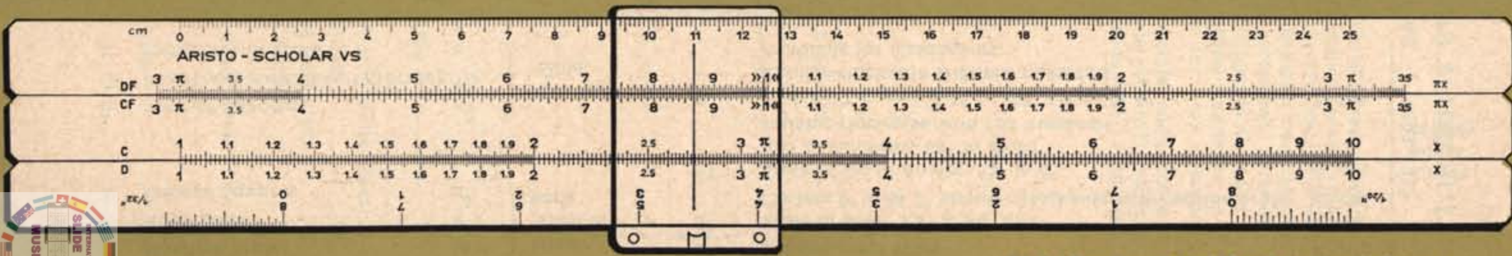


Fig. 2 Rear face of 0903 VS with double-sided cursor

The reverse side of the slide of the ARISTO Scholar LL contains a Log Log scale in two sections, LL2 and LL3, for computations involving powers, roots and logarithms. A second movable sine scale simplifies problems in trigonometry.

Rear Face — Body:	Millimeter Scale		
	Inch Scale		
Rear Face — Slide:	S	Sine Scale of Angles 5.5° to 90°	∢ sin
	LL2	Log Log Scale, Range 1.1 to 3	$e^{.1x}$
	LL3	Log Log Scale, Range 2.5 to 50.000	e^x

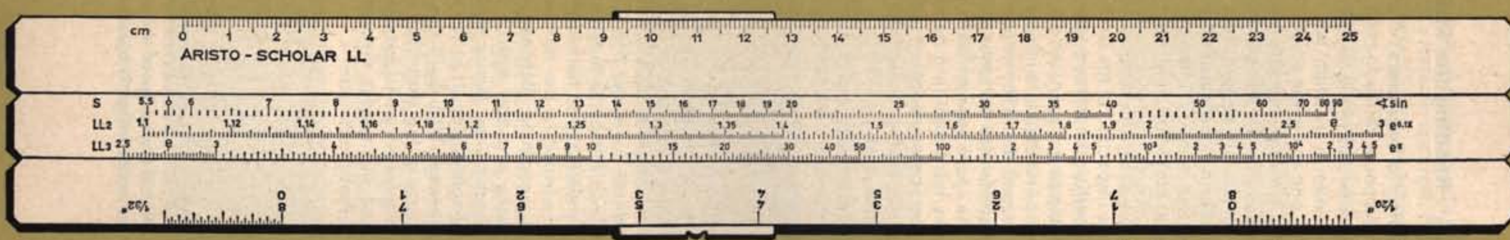


Fig. 3 Rear face of slide of 0903 LL

In the special case of the right triangle, since sin 90° = 1 we write in proportion form:

$$\frac{c}{1} = \frac{a}{\sin\alpha} = \frac{b}{\sin\beta} = \frac{a}{\cos\beta} = \frac{b}{\cos\alpha}$$

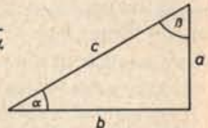


Fig. 20

Examples:

Given c = 5 a = 3

To find b, α, β

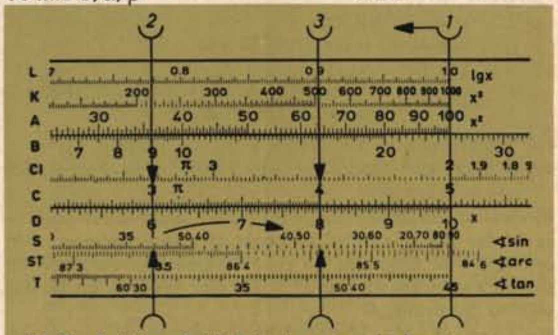


Fig. 21 Solution of right triangles, given the hypotenuse

Set c = 5 on the C scale opposite the right index of D. Shift the cursor to a = 3 on the C scale and read the angle α = 36.88° on the S scale. Leaving the slide undisturbed, shift the cursor to α = 36.88° (red) or β = 90° − α = 53.12° (black) on the same scale and read the side opposite the angle, b = 4, on the C scale. All variations of this problem are solved by similar procedures, except when the given elements are the two legs. In this case proceed as follows:

Given a = 3 b = 6 To find c, α, β

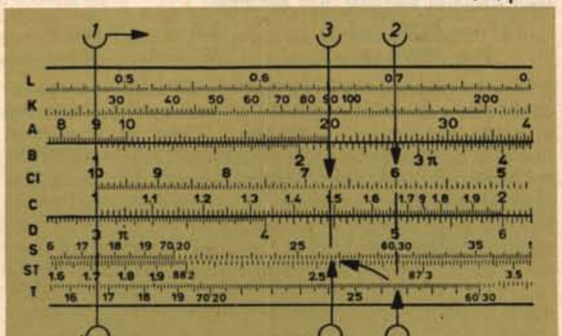


Fig. 22 Solution of right triangles. To find hypotenuse

$\tan\alpha = \frac{3}{6} = 3 \times \frac{1}{6}$. Set index of C to 3 on D. Under 6 of the CI scale find α = 26.6° on the T scale. With the slide kept in place and by cursor shift to 26.6° on the S scale, determine c = 6.71 on CI, since from $\sin\alpha = \frac{a}{c}$ we can derive the proportion $\frac{a}{1} = \frac{\sin\alpha}{1/c}$.

β = 90° − 26.6° = 63.4°

12. The Mantissa Scale L

Like a table of logarithms this scale only supplies the mantissa part of a logarithm.

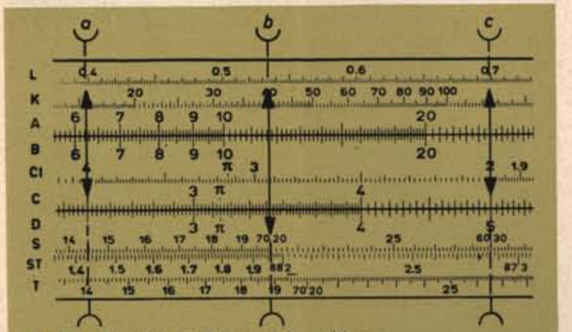


Fig. 23 Decadal or Common logarithms

a) log 2,5 = .3980 b) log sin 20° = 9.5340−10

c) antilog 1.6990 = 50

13. The Log Log Scales LL2 and LL3

(Applies to ARISTO Scholar LL only)

The rear face of the ARISTO Scholar LL (fig. 3) carries a Log Log scale in two sections, LL2 and LL3, numbered from 1.1 through 50000. Within this range calculations involving any power, root or logarithm can be performed. For this purpose the slide is inserted back to front.

Directions for using the Log Log scales will here be given in condensed form. For a more detailed description of the scales and their applications refer to the instructions for the ARISTO Darmstadt slide rule.

13.1 Powers

Two line segments are added together in a manner similar to ordinary multiplication. Set the given number on the LL scale opposite either index of D. Move the cursor to the exponent on D and read the power on the respective LL scale.

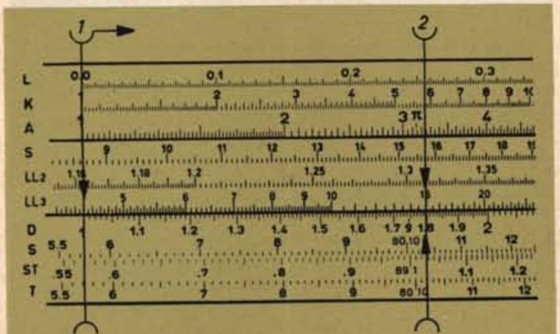


Fig. 24 $4.5^{1.8} = 15$

With this adjustment the rule is in tabulating position for raising the base 4.5 to any power. For power exponents smaller than 1, read the power on the adjacent scale LL2, as in $4.5^{.18} = 1.311$.

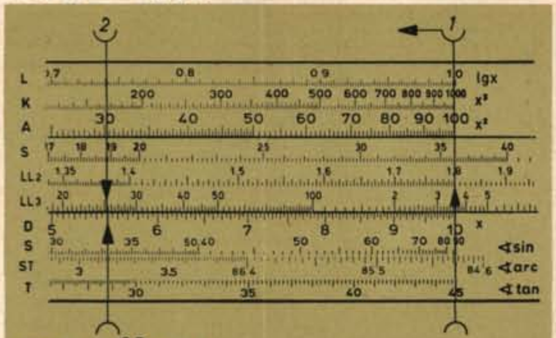


Fig. 25 $1.8^{5.5} = 25.4$

Set 1.8 on LL2 over the right index of the D scale and refer to LL3 for the answer. This switch from LL2 to LL3 is always necessary when the problem is set with the right index of D, since, LL3 is the extension of LL2 and naturally for any exponent > 1 the power cannot be smaller than the base.

Note: Contrary to the fundamental scales, the Log Log scales give all values with the decimal point definitely and unalterably inserted. The answer in fig. 25 can therefore only mean 25.4, NOT 2.54, or 254.

13.2 Compound Interest

In practice compound interest is usually computed by use of special tables. For this reason a prolongation of the LL scale to the range 1.01 to 1.1 has been omitted in preference to the more important second sine scale on the slide. When it is desired to demonstrate the theories of compound interest computation by slide rule, a rate of interest higher than 10% must be assumed.

An investment of 1500.—draws p = 12% of interest, compounded annually. Find the growth factor q^n and the compound amount after n = 1.5 years at interest.

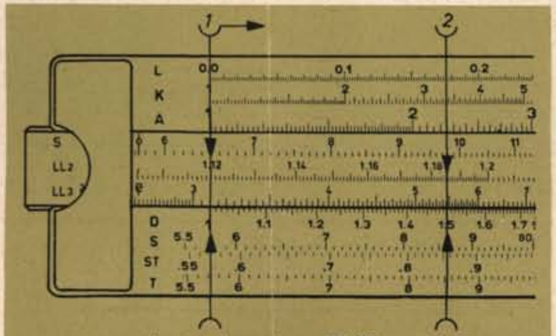


Fig. 26 $q^n = \left(1 + \frac{p}{100}\right)^n = \left(1 + \frac{12}{100}\right)^{1.5} = 1.12^{1.5} = 1.185$

The initial capital multiplied by 1.185 then gives the compound amount after 1.5 years.

Compound amount: $1500 \times 1.185 = 1778$.

13.3 Roots

Subtracting one segment of scale from another, as in division. The inverse process of raising a number to a power: $3^2 = 9 \rightarrow \sqrt[2]{9} = 3$.

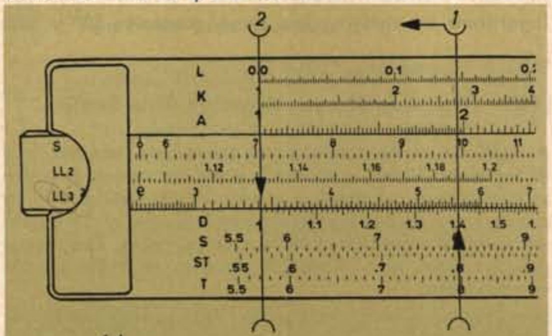


Fig. 27 $\sqrt[1.4]{5.6} = 3.42$

Set the radicand 5.6 on LL3 opposite the radical index 1.4 on D. Read the root 3.42 over the left index of D on LL3.

It is worthy of note that when this manipulation is completed the setting of the rule is also identical to that for the power $3.42^{1.4} = 5.6$. The only difference between both calculations (root and power) is the order of the setting and the reading.

13.4 Logarithms

The second reversal of the process of raising a number to a power:

$$10^2 = 100 \rightarrow \log_{10} 100 = 2$$

Logarithms to any base are found by setting the base on the LL scale opposite the left or right index of D and reading the logarithm on D opposite the antilog in LL.

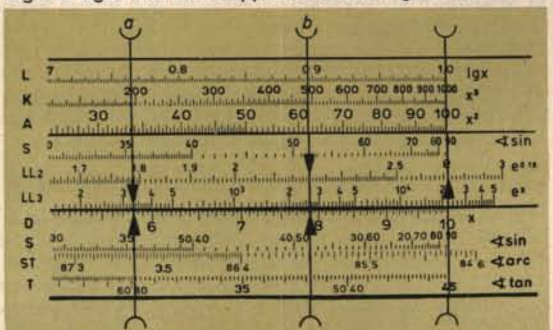


Fig. 28 Natural logarithms
a) $\log_e 330 = 5.80$ b) $\log_e 2.2 = .788$

When the rule is closed, both indexes of D are in match with the mark for the constant e on the two LL scales. Any logarithm to the base e can, therefore, be instantly read by cursor aid.

When the base 10 on the LL3 scale is set opposite the left index of D, the slide rule can be regarded as a graphical table of decadal logarithms. When, with the rule so adjusted, the cursor hair is placed over 2 on the D scale, we obtain a clear optical demonstration of the system by which the scales interact with one another in powers, roots and logarithms by studying the three processes $10^2 = 100$, $\sqrt[2]{100} = 10$, and $\log_{10} 100 = 2$.

14. The Additional Movable Sine Scale

(Applies to ARISTO Scholar LL only.)

A duplicate of the sine scale is printed on the rear face of the slide. This is a movable scale by means of which multiplication and division of one trigonometric ratio by another can be performed directly from the given angles without first ascertaining the numerical ratios. This means greater speed and improved accuracy in trigonometric computations.

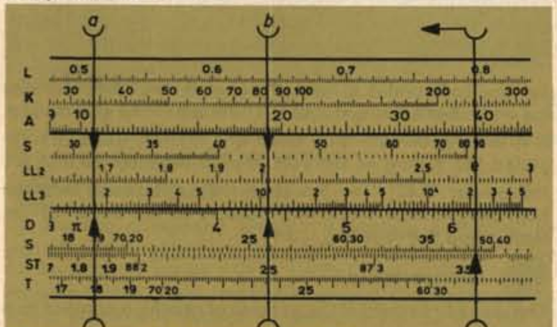


Fig. 29 a) sin 38.6° × sin 31.2° = .323
b) sin 38.6° × cos 45.5° = .437

Note that here the mark ⚲ or the 90° line on the sine scale take the place of the slide indexes in these operations. In dealing with expressions such as $a \times \sin\alpha \times \cos\alpha$,

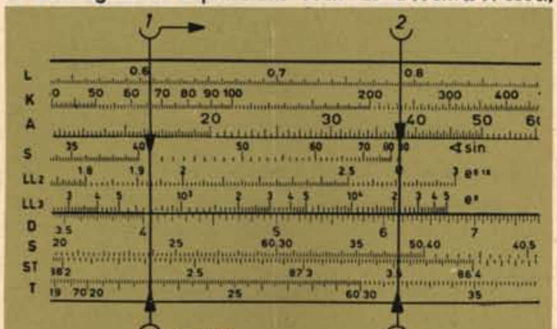


Fig. 30 $\tan\beta = \dfrac{\tan 22°}{\sin 41°}$ $\beta = 31.6°$

always start with the setting of "a" on the D scale. Formulas involving divisions are solved in a similar manner.

Set 22° on the T scale opposite 41° on the S scale on the reverse face of the slide and read the angle $\beta = 31.6°$ on the T scale under the cursor hairline set on the terminal mark 90° of the S scale.

Problems involving the law of spherical sines are just as easy to solve as similar problems in plane trigonometry. (Cf. chapter 11.)

15. The Four-Line Cursor

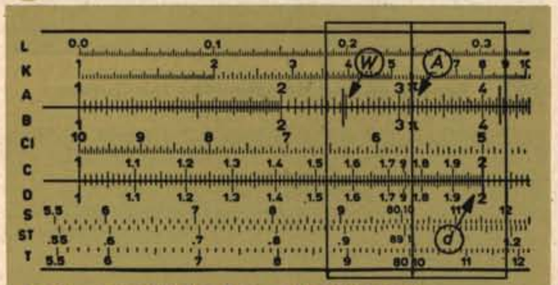


Fig. 31 Example: d = 2 in. → A = 3.14 sq. in.

15.1 Areas of Circles — Weights of Mild Steel Rods

The short lines to the upper left and lower right of the long cursor hairline are used to find the area of circles or round cross sections. These marks simplify multiplication with the factor $\pi/4 = .785$ in the area formula $A = d^2 \times \pi/4$.

Set the long hairline to the diameter d on the fundamental scale and read the answer $A = d^2 \times \pi/4$ under the left cursor hair. By reversing these steps, we obtain the diameter corresponding to the given area.

For users in countries where the metric system of weight and measurement is in force:

Since the specific weight of mild steel also happens to be 7.85 grams per cubic centimeter, it is easy to compute the weight of any running length of round rods. The short mark on the upper left of the cursor gives the weight in grams per cubic centimeter corresponding to the respective rod diameter in centimeters set with the lower right mark. The rest is then a simple multiplication. This is best done with the A and B scales by simply drawing the index of B under the left cursor hair which is already properly placed on A.

15.2 Conversion between kW and HP

The interval between the upper right line and the center line represents the factor for converting kW to HP, and vice versa, on scale A.

Hence, when the center hairline is set to 19.5 kW, for example, on the scale of squares, then the upper right line indicates the equivalent in HP viz. 26.1 (fig. 32). Inversely, when the short right line is set to 7 HP the center line will produce the equivalent: 5.22 kW.

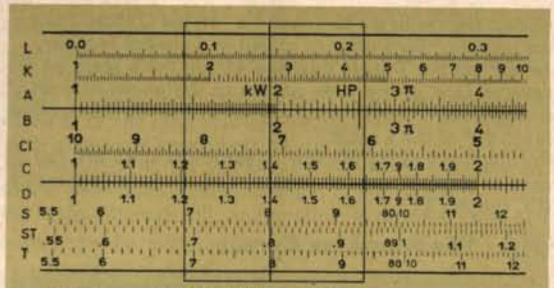


Fig. 32 Conversion 19.5 kW = 26.1 HP

15.3 Removing and Re-attaching the Cursor

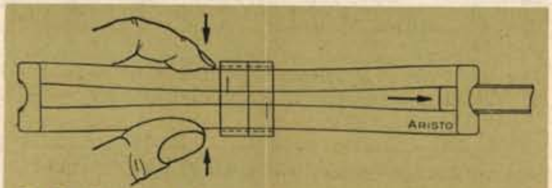


Fig. 33 Removing the cursor

With slide drawn well toward the right or left of the body, press the two body panels slightly together. The cursor can then be taken off or replaced (fig. 33).

Broken cursor springs can be easily exchanged, as shown in fig. 34. For replacements apply to your dealer.

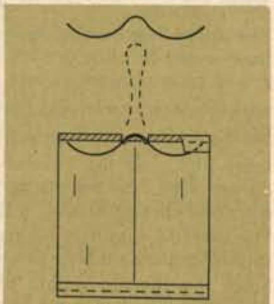


Fig. 34

16. The Double Face Cursor of the *ARISTO* Scholar VS-2

16.1 Detaching and Re-attaching the Cursor

Insert coin into slot in edge opposite the cursor spring. Twist slightly to open the two cursor sides. Remove the slide, squeeze the body panels slightly together and withdraw the cursor crosswise. This leaves the adjustment undisturbed provided that the adjusting screws are not loosened. Don't spread the cursor windows with undue force as this may cause breakages.

To re-attach the cursor, remove the slide and open the cursor sufficiently to pass over the rule (marks kW and HP over the A and B scales). Press the body panels slightly together so as to make the cursor rails engage the grooves in which they glide. Replace the slide.

16.2 Cursor Adjustment

Slacken the two adjusting screws and align the cursor hairline to the rear index of the D scale and the π-mark of the DF scale on the VS face of the slide rule. With this adjusted side held firmly in place, turn the rule over and place it on a table. Adjust the second side by means of the end lines of the scales L and T. Retighten the screws.

16.3 The Mark 36

The interval between the short cursor hair on the upper right and the center hair of the VS side represents the multiplication factor 36 for any switch from the D scale to DF, or respectively from C to CF. In reversed reading order it represents the divisor 36. This cursor mark makes the ARISTO Scholar VS useful in business courses, since it provides the means for the rapid solution of days-at-interest problems in a manner similar to that of any special slide rule for business use.

Another practical application of this mark consists in conversions between hours and seconds, degrees and seconds, and m/s and km/h.

17. Treatment of the *ARISTO* Slide Rule

The instrument is a valuable calculating aid and deserves careful treatment. Scales and cursor should be protected from dirt and scratches, so that the reading accuracy may not suffer.

It is advisable to give the rule an occasional treatment with the special cleanser fluid DEPAROL followed by a dry polishing. Avoid chemical substances of any description as they are almost certain to spoil the scales.

The slide rule must be protected from plastic erasers and their abrasive dusts, which can damage the surface of the material ARISTOPAL. Avoid also exposure to hot surfaces or bright sunshine, because at temperatures of about 140°F (60°C), distortion occurs. Rules so damaged will not be exchanged free of charge.

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2. Reading the Scales

Advice to beginners: Proficiency in slide rule operation presupposes ability to read the scales correctly.

The intervals in the logarithmic scales of a slide rule are not uniform in width but shrink progressively as we go from one end to the other. On the D scale, for instance, the main intervals marked with large numerals 1 to 10 are divided into ten so-called secondary intervals throughout the scale. But only in the range 1 to 2 is there room for numbering these secondary intervals and subdividing them into ten tertiary intervals, thereafter division is into 5 tertiary intervals, and, still later, to only 2 tertiary intervals.

Let us study the three recurrent types of subdivision by close inspection of the D scale, whose large numerals, 1 to 10, outline the framework of the entire system.

1. Within the range 1 to 2, the large numerals represent the first digit in a number and the smaller numerals the second digit. For example, the line opposite 1.3 is the location for the sequence 1-3. The shorter lines dividing the space between each two numbered lines represent the third digit in a number. 1-3-2 for instance. Within the space separating any two of the smallest division lines, the fourth digit can be easily located by eye judgement, such as 1-3-8-3.

   This is analogous to reading the decimeters, centimeters, millimeters and tenths of a millimeter on a metric scale.

Fig. 4 Reading the scales within the range 1 to 2

2. Within the range 2 to 4, only the first digit can be read directly from the numbering. The second digit is located by counting off the intervening longer division lines, as illustrated by the numbers printed in brackets — (22) for example. Between each two long division lines there are now only 5 tertiary intervals, marked by shorter lines. Hence each progression marks two units of subdivision, i. e. the **even** third digits 0-2-4-6-8. All **uneven** third digits are located by inspection in mid-space of the respective interval — 215 and 203 for examples — whilst between the midpoint of the interval and the nearer division mark a fourth place can be visually estimated, e. g. 2075.

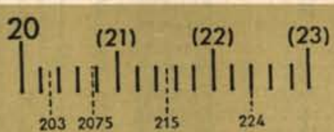

Fig. 5 Reading the scales within the range 2 to 4

3. Within the range of the numbered division lines 4 to 10, the second digit is again counted off on the longer lines, as the bracketed values show. A short line splits each secondary interval into only two tertiary intervals. Hence the third digit is here always either 5 or 0, as the sample reading 515 shows.

   Third digits other than 5 or 0 are located by inspection — 549 for example.

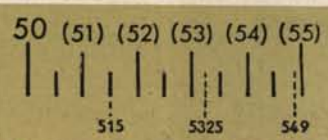

Fig. 6 Reading the scales within the range 4 to 10

A mistake often made by beginners is that of omitting the zero when locating numbers in the ranges immediately following each one of the labeled longest division lines. Now take a look at the very first interval and reason out for yourself why there must even be two zeros following the "1". Refer to the sample 1-0-0-7 in fig. 7.

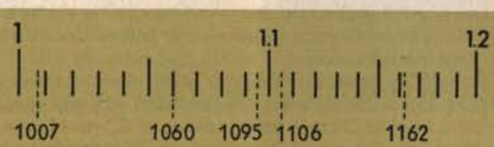

Fig. 7 Where zeros are often forgotten

To avoid mistakes, it is good practice to express all numbers digit for digit. The number 132, for instance, should be pronounced one-three-two. The setting 1-3-2 applies to the number 132 as well as to any decimal variant thereof, such as 1.32, 0.132, 1320 etc. etc. The correct place for the decimal point in the final answer is determined by rough approximation with values reduced to round numbers.

The C scale is an exact counterpart of D. For reading exercises it is advisable to line up both scales from end to end, so that the finding of numbers can be practised on both scales simultaneously. It is further suggested to follow up these reading exercises by practice with the A and B scales which have a similar system of subdivision but in changed order. The main intervals 1 to 10 are here printed twice, in sequence, each section having half the length of a normal scale.

Where, in elementary courses or for self-instruction, a simple slide rule with only the essential scales is desired, the rear face of the ARISTO Scholar VS or the ARISTO Scholar VS-2 meets these requirements admirably. It contains only a second pair of C and D scales, supplemented by their "folded" counterparts CF and DF. The other Scholar models have the fundamental scales C and D on the front face only. These latter two scales will be used exclusively in the sample problems of chapter 3.

3. Multiplication

The process of adding two segments of logarithmic scales

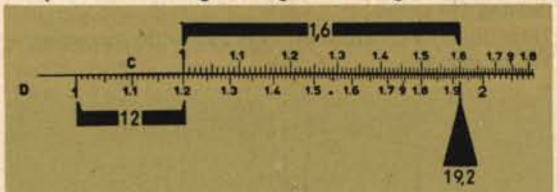

Fig. 8 12 × 1.6 = 19.2

The distance from 1 to 12 on the D scale and the distance from 1 to 1.6 of the C scale are added graphically by placing the 1 (called the left index) of C opposite 12 on D. Under 1.6 of C then read on D the answer 19.2, viz. the product of 12 × 1.6 = 19.2. The black brackets in Fig. 8 represent the two distances, and the arrow head points to the product.

In the example 8 × 7 = 56 the above procedure must fail, because the slide would project so far outside the rule that no reading would be possible on the D scale. In this case the end line 10 (called the right index) of C is set to 8 of D. If a duplicate D scale were placed before the existing one, then the left index of C would also coincide with 8 on this imaginary scale and the two given lengths could be added in the usual manner. On reflection you will realize that on a double D scale both indexes of C would invariably be located over identical values. This leads to the further conclusion that there is no need for a second D scale. With the existing single D scale, all we have to do is to substitute one index for the other whenever the necessity arises.

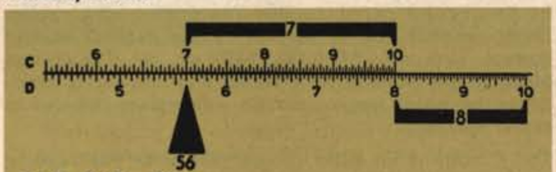

Fig. 9 8 × 7 = 56

The black brackets in fig. 9 are not quite correctly placed because they really represent the tail ends of the logarithmic distances drawn from 10 backwards. However, the actual setting is presented with greater clarity than in a strictly correct diagram. The process of changing one index for the other is usually termed "resetting the slide" and never fails to produce the answer whenever the D scale falls out of reading range.

4. Multiplication with the Scales CF and DF

(Applies to ARISTO Scholar VS and VS-2 only.)

The scales CF and DF are similar in design and mode of operation to the C and D scales, except that their graduations are displaced sideways relative to those of C and D. This transfers the 1 to a position in the middle of the graduation, where it constitutes at the same time the beginning and the end of the scale. The section to the right of this center index is a reproduction of the first part, and the section to the left of it, the end part of a regular fundamental scale. Another way of explaining the layout is to regard a "folded scale" as the middle half cut out of two normal scales running in sequence. For computations involving the use of the folded scales, transfer the cursor to the rear face of the rule. How this is done is explained in chap. 15.3. No cursor reversal is necessary when the slide rule is equipped with the double face cursor VS-2.

The problem 12 × 1.6 of fig. 8 can, of course, also be solved with the CF and DF scales by setting the index 1 of CF to 12 of DF. This brings out the important fact that, simultaneously, the left index of the C scale has performed a corresponding motion to the value 12 on D, i. e. exactly the setting used in the solution illustrated in Fig. 8.

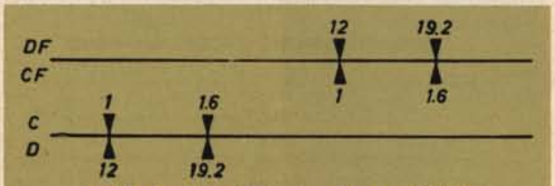

Fig. 10 Readings identical on C/D and CF/DF

Now take a glance along the two pairs of scales and observe that the ratio of any number on one scale to the number opposite on its companion scale is constant throughout the entire system C/D and CF/DF. From this it follows that (1) the initial setting for the multiplication can be made with either pair of scales, and (2) where the readability of one pair of scales ends, the other pair always supplies the answer. This, of course, applies to all problems, provided that no more than half a slide length projects out of the rule for the first setting. We don't even have to heed this supposition. When the first setting is made with CF over DF, the reading range is always unlimited.

Take the second example 8×7 = 56 and let us assume that a large variety of other values has to be multiplied by 8 also. Note that, when the first setting is made with CF and DF, the effect is as shown in fig. 9. No need to choose between the two slide indexes. All products of 8 multiplied by any other factor are now readable on C and D or CF and DF, respectively.

Exercises: 18 × .285 = 5.13 (on D)
18 × 7.8 = 140.4 (on DF)

Multiplications involving the constant π are particularly easy and convenient to perform, since π on CF and DF is permanently located opposite the indexes of C and D, respectively, as a constant factor. If, for instance, the diameter 65″ of a circle is set by cursor on the D scale, the circumference, 204″, appears directly under the hairline on DF. And vice versa, of course.

5. Division

The process of subtracting one segment of logarithmic scale from another. (Multiplication in reverse.)

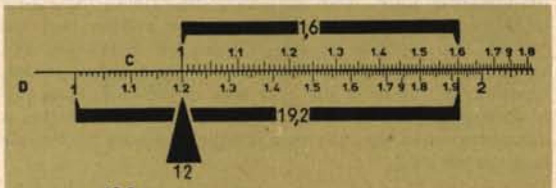

Fig. 11 $\frac{19.2}{1.6} = 12$

Place the divisor on the C scale opposite the dividend on D and read the quotient on the D scale opposite the index of C.

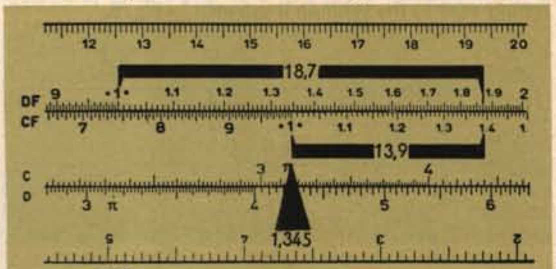

Fig. 12 $\frac{18.7}{13.9} = 1.345$

In division the use of the folded scales of the ARISTO Scholar VS or VS-2 has the advantage that the problem can be set in the widely used fractional form of notation, as given above. The numerator then appears on DF and the denominator below it on CF (i. e. in their logical order) The quotient appears opposite the respective indexes of CF as well as of C.

Exercises: 894÷31 = 28.84 Roughly: 900÷30 = 30
42÷53 = .7925 Roughly: 40÷50 = .8

6. Combined Multiplication and Division

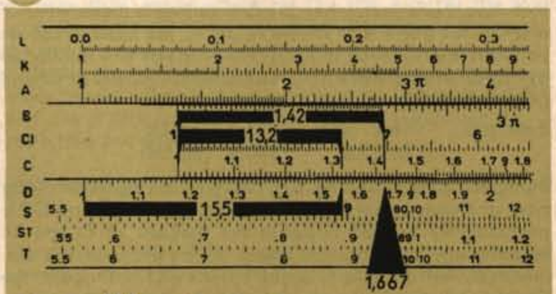

Fig. 13 $\frac{15.5}{13.2} \times 1.42 = 1.667$

Rule: Division comes first, followed by multiplication. The intermediate result can be ignored.

After performing the division, the slide is always in the correct position for the subsequent multiplication. In many problems, however, the slide will have to be reset to obtain the product and the advantage of starting with the division is lost. With the ARISTO Scholar VS or VS-2 this will not happen, since the computation can always be completed on CF and DF without slide manipulation. Better still, start with the division on CF and DF. The multiplication can then often be done with both pairs of scales, in other cases with the one or the other pair.

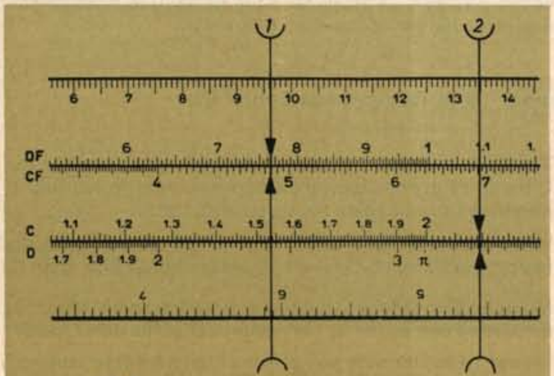

Fig. 14 $\frac{76.4}{4.85} \times 2.19 = 34.5$

7. Proportion and Tabulation

Problems in proportion are particularly easy to solve by slide rule. The juncture separating the slide from the body may be regarded as the dividing line in the ratios written in fractional form. From old habit rule-of-three problems are usually solved as discussed in chapter 6. But the slide rule greatly facilitates and simplifies solution when the problem is expressed in proportion form.

For example: $\frac{6.5}{8.75} = \frac{4.05}{?} = \frac{\text{lb}}{\$}$

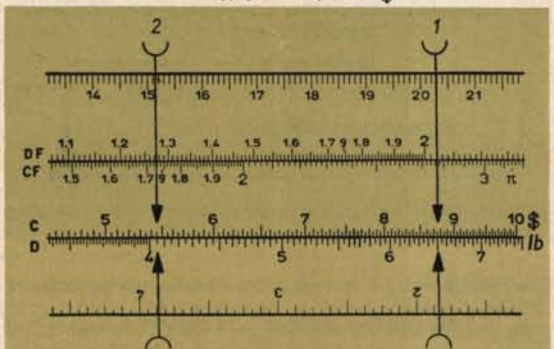

Fig. 15 Proportion

The above proportion may be the answer to some such problem as: 6.5 pounds of a commodity are worth $ 8.75. How much for 4.05 pounds?

With the initial setting of 6.5 on D opposite 8.75 on C we can compile a list of all desired weight/price relations. With the ARISTO Scholar VS or VS-2 it will not even be necessary to reset the slide when a ratio falls beyond reading range of C and D, because the CF and DF scales will then take over: 9.8 pounds are worth $ 13.20 etc. etc.

In the case of complex formulas, a competent slide rule operator will always aim at their solution by application of the principle of proportion for its obvious advantages. See also chapter 11 for a case in point.

8. The Reciprocal Scale CI

The CI scale supplies the reciprocals of numbers set on the C scale. Its graduation advances from right to left and is numbered in red color for better distinction.

When the cursor is set to 5 on C, then the CI scale gives the reciprocal 1/5 = .2. Conversely, under 5 of CI find .2 on C.

Multiplication of two numbers has the same effect as division of one factor by the reciprocal of the other factor:

$$4 \times 5 = \frac{4}{1/5} = 20$$

$$\frac{4}{5} = 4 \times \frac{1}{5} = .8$$

Hence, by use of the CI scale a division can be changed to a multiplication and vice versa.

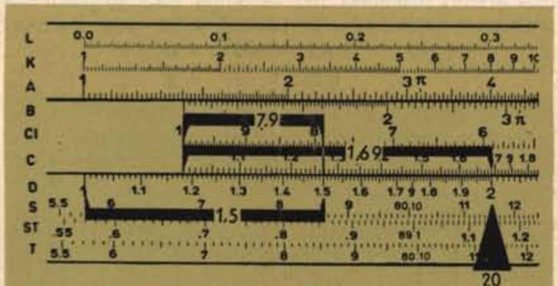

Fig. 16 Use of the reciprocal scale

Exemple: 1.5 × 7.9 × 1.69 = 20. Change the example to $\frac{1.5}{1/7.9} \times 1.69$. Solution analogous to chapter 6, except that 7.9 is set on CI.

9. The Scales A, B and K

Reading from D to A or C to B for squares, from D to K for cubes, and vice versa for the roots.

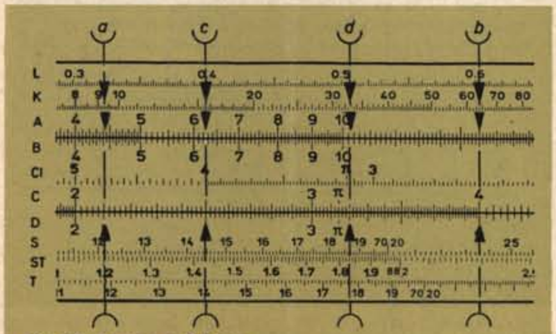

Fig. 17 Powers and Roots

a) $2.1^2 = 4.41$ $\quad 2.1^3 = 9.26$

b) $\sqrt{16} = 4$ $\quad \sqrt[3]{64} = 4$

c) $25^2 = 625$ $\quad 25^3 = 15620$

d) $\sqrt{1024} = 32$ $\quad \sqrt[3]{.03277} = .32$

The place of the decimal point is best determined by rough approximation. Observe that the scale of squares is numbered progressively from 1 through 100, and the cube scale from 1 through 1000. When extracting roots it is recommended to reduce the radicand to a power-of-ten notation in order to obtain values that will lie between the above given numerals of the scales.

$$\sqrt{3200} = \sqrt{32 \times 100} = \sqrt{32 \times 10^2} = 10 \times \sqrt{32} = 10 \times 5.66 = 56.6$$

$$\sqrt[3]{0.03277} = \sqrt[3]{\frac{32.77}{1000}} = \frac{1}{10}\sqrt[3]{32.77} = 0.32$$

The scale section in which the cursor setting has to be made is determined from the scale numbering. Multiplication and division can also be done by using the scales A and B by the same process as that for C and D, but the precision obtained will be somewhat less refined.

10. The Trigonometrical Scales S, ST and T

Scales S, ST and T provide, in association with the fundamental scale S, sine and tangent values. For any angle located by the cursor on scale S (for sines) or scale T (for tangents), the corresponding function value can at once be read on scale D, between 0.1 and 1.0. Conversely, given the function value, the angle can be found.

The decimally divided scales S and T are figured in degrees only. The overriding importance of these scales lies in the fact, that in trigonometrical calculations, the function itself is not necessarily to be read. Examples of such readings are however given:

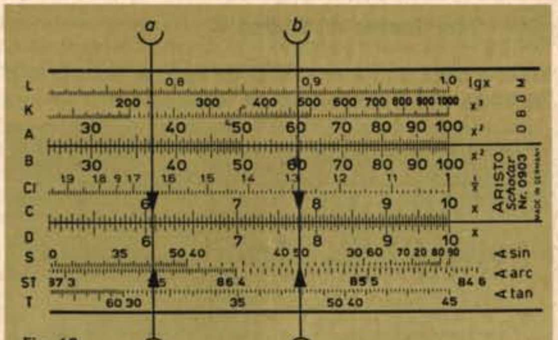

Fig. 18
a) sin 37.4° = .607 (set cursor to 37.4° on scale S, read result on D, .607)
b) cos 39° = sin (90°—39°) = sin 51° = .777.

The cosine of an angle is read as the sine of its complement. Because, in reading the scale backwards, the complement (90° — α) can easily be miscalculated, the scale is also figured, in red, in the reverse direction. Taking 90° as 0°, 80° is then read as 10°, 70° as 20° and so on. For readings on scale S the following "colour rule" is useful:

Sines: read black figures of scale S.
Cosines: read red figures of scale S.

The scale of tangents coincides at tan 45° = 1 with the end mark of scale D. For tangents of angles > 45° the formula tan (90° — α) = 1/tan α can be used. The complementary angle can be calculated or, alternatively, be found at once with the aid of the red figuring of scale T. Because tangent values are read on scale D, the reciprocal values 1/tan α can at once be found on scale CI, between 1 and 10, if the slide indices are brought into coincidence.

Those who have learned to read the tan function easily will also find the cotangents without difficulty, since these

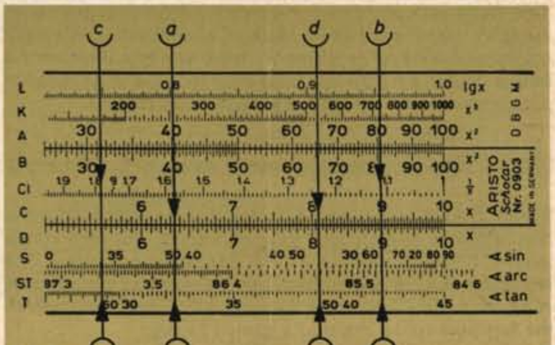

Fig. 19
a) tan 32.4° = .635 Read scale D
b) tan 48° = 1.111 Read scale CI (All scales lined up)
c) cot 29.3° = 1.782 Read scale CI (All scales lined up)
d) cot 51° = .810 Read scale D

are quite simply the reciprocals of the tangents, as given by cot α = 1/tan α. It follows that the cotangent of any angle smaller than 45° is found on the CI scale and of angles larger than 45° on D.

Here another useful colour rule:

Like colours used in setting and reading produce the tangent of the given angle, unlike colours its cotangent.

Practice Problems:

sin 41.5° = .663
cos 32.2° = sin 57.8° = .846
tan 12° = .2126
cot 82° = tan (90°—82°) = tan 8° = .1405
tan 62° = cot 28° = 1/tan 28° = 1.88

For **Small Angles** we have the approximation:
$\sin\alpha \approx \tan\alpha \approx \cos(90°-\alpha) \approx \cot(90°-\alpha) \approx \frac{\pi}{180} \times \alpha$
≈ α in radians

In view of the above statement the ST scale is designed to serve for the sines and tangents of angles between .55° and 6°. The functions of such angles are obtained by setting the angle on the ST scale and reading on D, but adding the prefix .0.

For **Large Angles** between 84° and 89.45° whose cofunctions are required, the setting is made easy by the provision of a red right-to-left figuring attached to the ST scale.

The ST scale is spaced in radian measure, but its numerations denote degrees. The effect is that the reciprocity Degrees ←→ Radians exists between ST and D. Considering that the trigonometric scales are subdivided in the decimal system instead of sexagesimally, it is not only possible to convert the actually readable angles, but also their decimal variants. For example:

5° = .0872 rad	50° = .872 rad
.5° = .00872 rad	57° = 1 rad

It may be added for clarity that the ST scale is a reproduction of a fundamental scale with a scale displacement of π/180, but figured in degrees. Over its 1°-division line will be found the mark π/180 = .01745 on D. When the index of the C scale is lined up with this mark, the D scale once more produces the radian equivalent or the function of any angle in the above ranges set on C. This note is important to users of those slide rules which have no ST scale. The corresponding marks on scales C and CI make possible multiplication and division by $\frac{\pi}{180}$ and $\frac{180}{\pi}$, respectively.

11. Solution of Triangles

The law of sines $\frac{a}{\sin\alpha} = \frac{b}{\sin\beta} = \frac{c}{\sin\gamma}$ is a classic example of the principle of proportion in practical application. (See chapter 7.) By setting the given angle on S opposite the given side on D, the other ratios are immediately in coincidence, i. e. the angle corresponding to the given side or the side opposite the given angle are directly available.