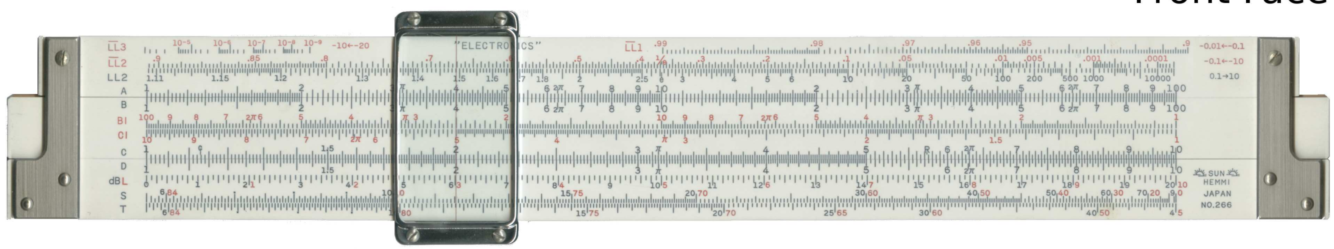
HEMMI

INSTRUCTION MANUAL FOR HEMMI 266 SLIDE RULE

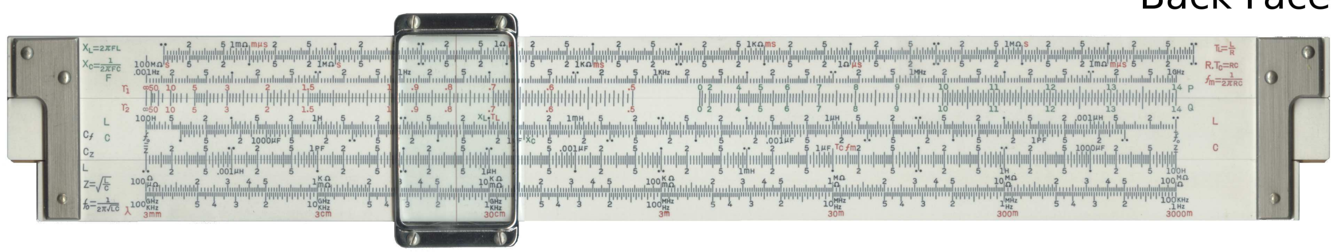
HEMMI SLIDE RULE CO., LTD.
TOKYO, JAPAN

No. 266 Slide Rule

Front Face



Back Face



Contents

Forward

Over the years my relatively small slide rule collection has tended slightly towards special purpose rules and especially those for electronics. That's not surprising since I spend my days working as an electronics engineer. At long last in 2008 I bought a Hemmi 266, factory fresh after decades of storage. When Hemmi discovered they could still sell these rules to the slightly off center and enthusiastic slide rule collectors out there, they seem to have quickly stitched up slide rule covers and duplicated the instruction manual.

Unfortunately on both counts, neither quite lives up to former Hemmi standards. The slide rule case might keep dust off, but won't protect the rule to any degree since it's very soft. The manual is simply made on a copy machine, complete with staple holes where pages were mistakenly stapled before being correctly bound, to use the term loosely. Disappointing to the collector, but certainly better than nothing.

Hemmi manuals, the original ones, can be difficult to clearly read because examples use tiny fonts. For that reason and also not wanting to damage the flimsy copy of the manual that I have, I typed in a page or two a day over the course of a couple months—notice the bigger pictures and fonts! The manual is typeset using LaTeX, a powerful text processor especially when it comes to mathematics, which is why it is the American Mathematical Society standard for its publications. Many engineering publications also accept only TeX or LaTeX formatted documents.

In the manual, I corrected a handful of significant mistakes in the electronics examples. Some engineering terms and English usage were also corrected, particularly in a case or two where the text was convoluted due to too direct a translation from Japanese, I imagine by translators without technical backgrounds. Please email me with any mistakes you discover. I expect I have inadvertently introduced some.

Also, do you have an extra original manual or Hemmi slide rule case? I hope to upgrade to originals, so email regarding them is welcome. I would also appreciate comments and ideas for improvement of this new version of the manual.

Enjoy!
Mike Markowski, August 2008
mm@udel.edu

Instruction Manual for Hemmi No. 266 $\left(\begin{smallmatrix}\textbf{25 cm}\\ \textbf{Duplex Type}\end{smallmatrix}\right)$ Electronics Slide Rule

This slide rule is especially designed to facilitate calculations in the field of ELECTRONICS. Calculations in many other fields in addition to general multiplication, division, square, etc. are also possible by utilizing the specially designed scales.

1. EQUIPPED WITH THE BI SCALE. Since this slide rule is equipped the B1 scale, multiplication and division involving square and square root often in electronics can now be simplified and performed much faster.

2. THE RANGE OF THE LOG LOG SCALES HAS BEEN EXPANDED. A of A^x of the LL scale, which is necessary for exponent calculations has been increased to cover the range from 1.11 to 20,000. The LL scale, when x is a minus value, has been increased to cover the calculating range from 10^{-9} to 0.99. Hyperbolic function is easier than ever to find since the log log scales are equipped on the reverse side of the LL scales.

3. IMPEDANCE AND REACTANCE CAN BE READ WITH THE DECIMAL POINT.
   Since this slide rule employs a 12 unit logarithmic scale, the value of L, C, R, X, F and T can be directly read on the slide rule with the decimal point. Any other calculation to find the location of decimal point is not necessary.

4. EQUIPPED WITH r_1, r_2 SCALES.
   The r_1 and r_2 scales make parallel resistance and series capacitance calculations possible. The P and Q scales permit rapid calculation of the absolute value of impedance.

5. THE SCALES ARE COLOR CODED.
   The scale signs and formulas are marked on the scale. The scales required for various calculations are color coded black, red and green to facilitate calculation.

Chapter 1

Reading the Scales

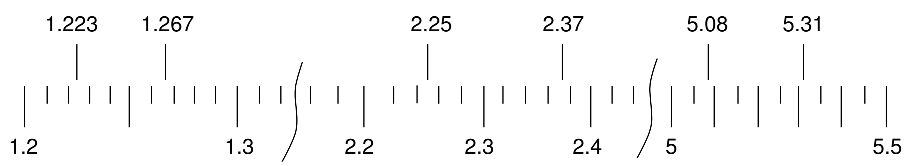
In order to master the slide rule, you must first practice reading the scales quickly and accurately. This chapter explains how to read the D scale which is the fundamental scale and is used most often.

1.1 Scale Divisions

Divisions of the D scale are not uniform and differ as follows:

Between $1 - 2$	one division is 0.01
Between $2 - 5$	one division is 0.02
Between $5 - 10$	one division is 0.05

Values between lines can be read by visual approximation. An actual example is given below.



1.2 Significant Figures

The D scale is read without regard to decimal point location. For example, 0.237, 2.37, and 237 are read 2 3 7 (two three seven) on the D scale. When reading the D scale, the decimal point can be generally ignored and the numbers are directly read as 2 3 7 (two three seven). In 2 3 7 (two three seven), the 2 (two) is called the first "significant figure."

1.3 Index Lines

The lines at the left and right ends of the D scale and labeled 1 and 10 respectively are called the "fixed index lines." The corresponding lines on the C scale are called the "slide index lines."

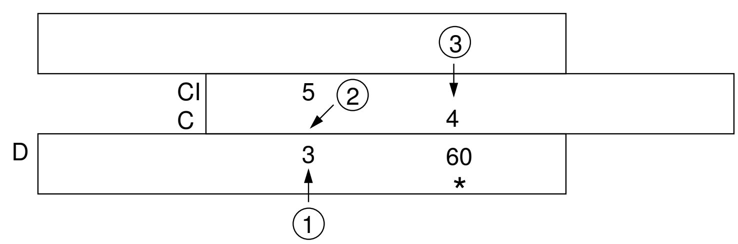
Slide Rule Diagram

For the reader's convenience, calculating will be explained in diagram form in this instruction manual. The symbols used in the diagrams are:

Slide Operation	↗↙↘↖	Moving the slide to the position of the arrow with respect to the body of the rule.
Indicator Operation	↓↑	Setting the hairline of the indicator to the arrow positions on the body and slide.
	*	The position at which the answer is read.

The numeral in the small circle indicates the procedure order. The below diagram shows the slide rule operation required to calculate $3 \times 5 \times 4 = 60$ using the C, D, and CI scales.

1. Set the hairline over 3 on the D scale.
2. Move 5 on the CI scale under the hairline.
3. Reset the hairline over 4 on the C scale and read the answer 60 on the D scale under the hairline.



(Note) The vertical lines at both right and left ends of the diagram do not indicate the actual end lines of the slide rule, but only serve to indicate the location of the indices.

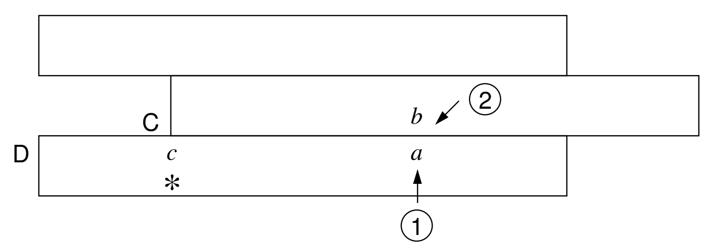
Chapter 2

Multiplication and Division

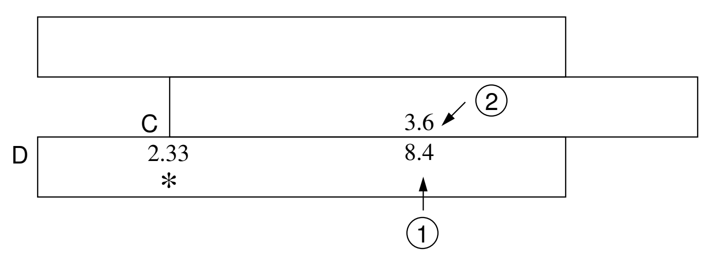
2.1 Division

FUNDAMENTAL OPERATION (1) $a \div b = c$

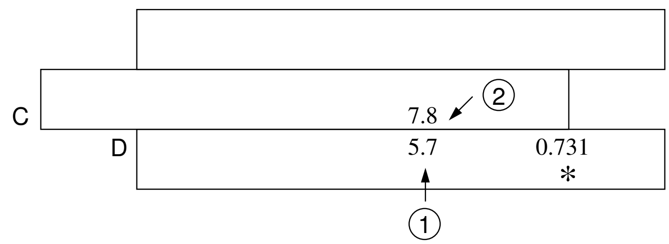
1. Set the hairline over a on the D scale.
2. Move b on the C scale under the hairline, read the answer c on the D scale opposite the index of the C scale.



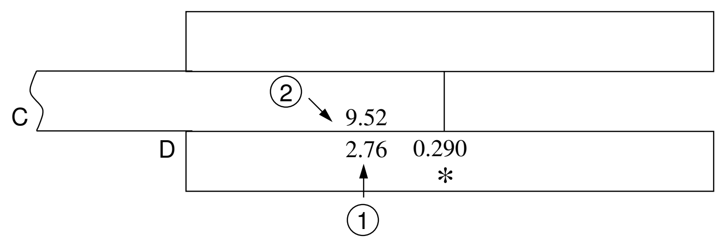
Ex. 2.1 $8.4 \div 3.6 = 2.33$



Ex. 2.2 $5.7 \div 7.8 = 0.731$



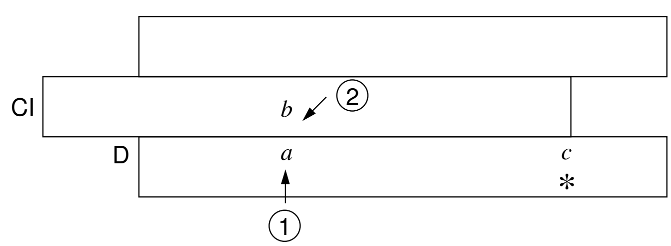
Ex. 2.3 $2.76 \div 9.52 = 0.290$



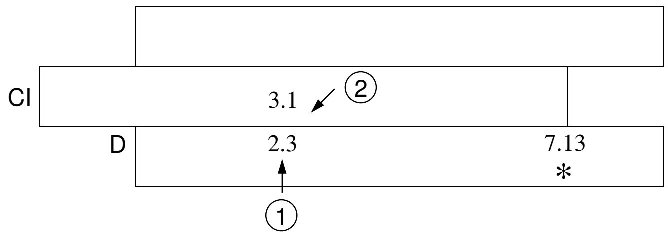
2.2 Multiplication

FUNDAMENTAL OPERATION (2) $a \times b = c$

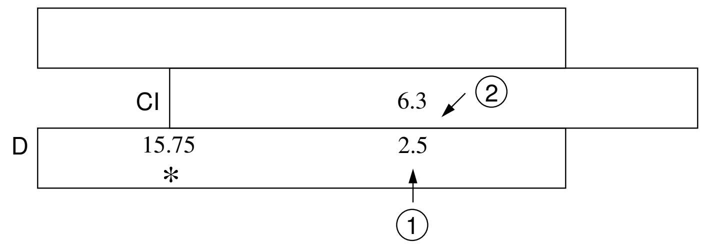
1. Set the hairline over a on the D scale.
2. Move b on the CI scale under the hairline, read the answer c on the D scale opposite the index of the CI scale.



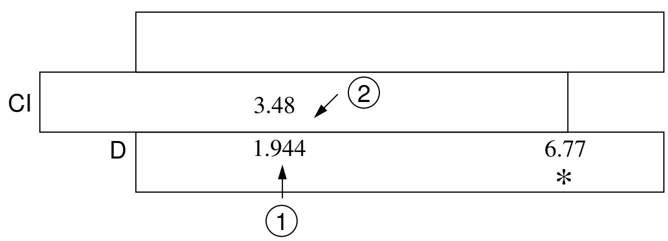
Ex. 2.4 $2.3 \times 3.1 = 7.13$



Ex. 2.5 $2.5 \times 6.3 = 15.75$



Ex. 2.6 $1.944 \times 3.48 = 6.77$



Chapter 3

Proportion and Inverse Proportion

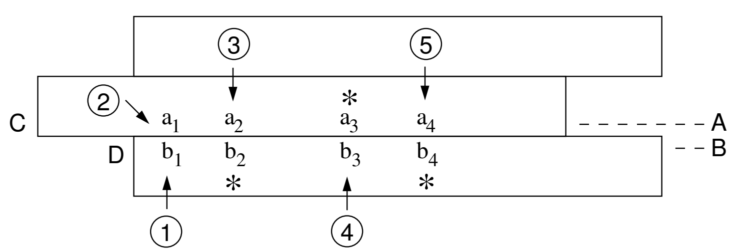
3.1 Proportion

When the slide is set in any position, the ratio of any number on the D scale to its opposite on the C scale is the same as the ratio of any other number on the D scale to its opposite on the C scale. In other words, the D scale is directly proportional to the C scale. This relationship is used to calculate percentages, indices of numbers, conversion of measurements to their equivalents in other systems, etc.

FUNDAMENTAL OPERATION (3) $A \propto B$

A	a_1	a_2	(a_3)	a_4
B	b_1	(b_2)	(b_3)	(b_4)

( ) indicates an unknown quantity

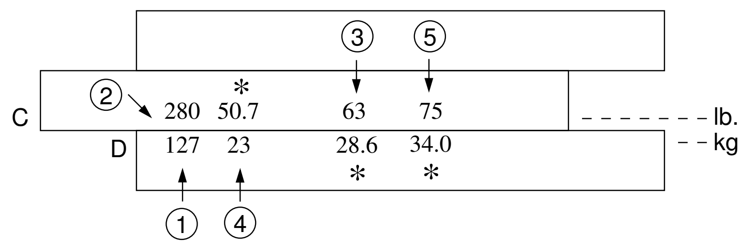


As illustrated in the above figure, when a_1 on the C scale is set opposite b_1 on the D scale the unknown quantities are all found on the C or D scales by moving the hairline.

Ex. 3.1 Conversion.

Given 127 kg = 280 lb. Find the values corresponding to the given values.

Pounds	280	63	(50.7)	75
kg	127	(28.6)	(23)	(34.0)



(Note) In calculating proportions, the C scale must be used for one measurement and the D scale for the other. Interchanging the scales is not permitted until the calculation is completed. In Ex. 3.1, the C scale is used for the measurement of pounds and the D scale for that of kilograms.

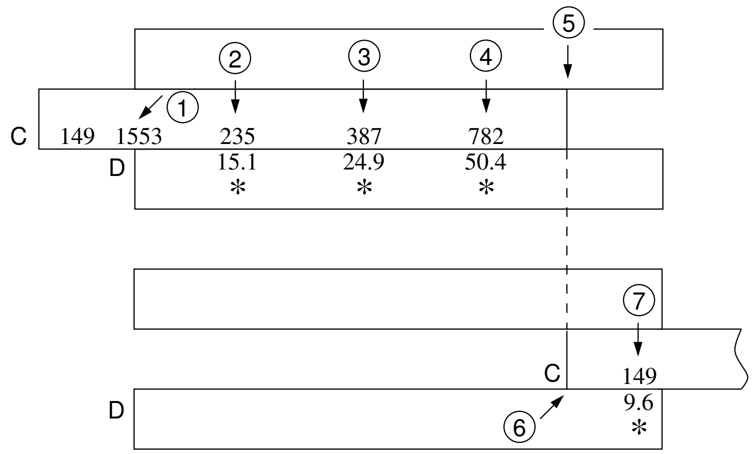
Ex. 3.2 Percentages.

Complete the table below.

Product	A	B	C	D	Total
Sales	235	387	782	149	1553
Percentage	(15.1)%	(24.9)	(50.4)	(9.6)	100

(UNIT: $10,000)

149 is on the part of the C scale which projects from the slide rule and its opposite on the D scale cannot be read. This is called "off scale." In the case of an "off scale," move the hairline to the right index of the C scale and move the slide to bring the left index of the C scale under the hairline. The answer 9.6 can then be read on the D scale opposite 149 on the C scale which is now inside the rule. This operation is called "interchanging the indices."



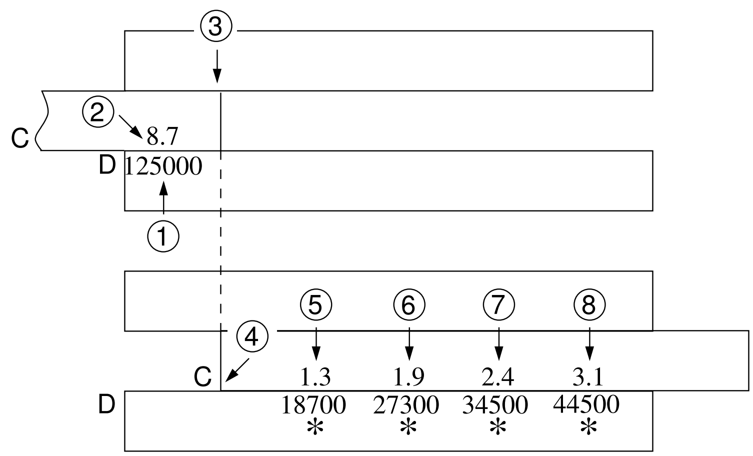
Ex. 3.3 Proportional Distribution

Distribute a sum of $125,000 in proportion to each rate specified below.

Rate	1.3	1.9	2.4	3.1	Total (8.7)
Amount	(18,700)	(27,300)	(34,500)	(44,500)	125,000

(UNIT: $)

When 8.7 on the C scale is opposite 125,000 on the D scale, 1.3, 1.9, 2.4, and 3.1 on the C scale run "off scale." Therefore interchanging the indices is immediately required.

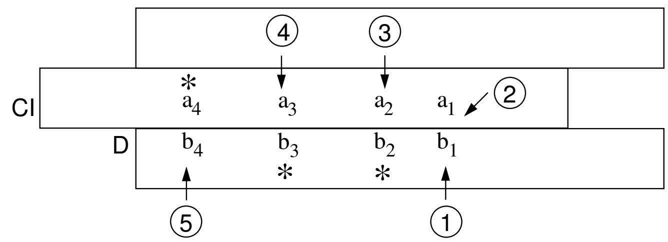


3.2 Inverse Proportion

When the slide is set in any position, the product of any number on the D scale and its opposite on the CI scale is the same as the product of any other number on the D scale and its opposite on the CI scale. In other words, the D scale is inversely proportional to the CI scale. This relationship is used to calculate inverse proportion problems.

FUNDAMENTAL OPERATION (4) $A \propto \dfrac{1}{B} \quad A \times B = \text{Constant}$

A	a_1	a_2	(a_3)	(a_4)
B	b_1	(b_2)	(b_3)	b_4

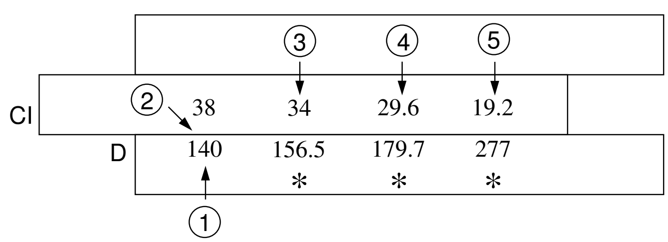


When a_1 on the CI scale is set opposite b_1 on the D scale, the product of $a_1 \times b_1$ is equal to that of $a_2 \times b_2$, that of $a_3 \times b_3$, and also equal to that of that of $a_4 \times b_4$. Therefore, b_2, b_3, a can be found by merely moving the hairline of the indicator.

Ex. 3.4

A bicycle travels at 38 km per hour, and takes 140 minutes to go from town to another. Calculate how many minutes it will take if the bicycle is traveling at 34 km per hour, 29.6 km per hour or 19.2 km per hour.

Speed	38 km	34	29.6	19.2
Time required	140 min.	(156.5)	(179.7)	(277)

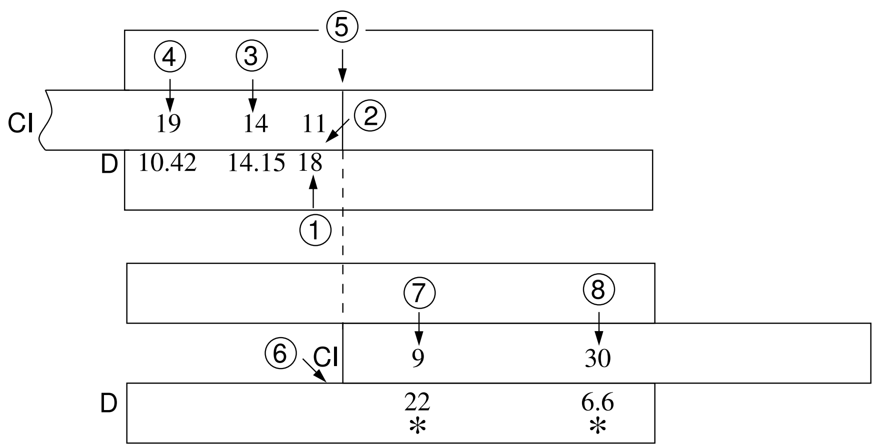


In solving inverse proportion problems, unlike proportional problems, you can freely switch the scales from one to another, but it is preferable to select and use the scales so that the answer is always read on the D scale. In Ex. 3.1 the answer is always read on the D scale since the given figures are all set on the slide.

Ex. 3.5

A job requires 11 men 18 days to complete. How many days will it take if the job is done by 9 men, 30 men, 19 men, and 14 men?

No. of men	11	9	30	19	14
Time required	18	(22)	(6.6)	(10.42)	(14.15)



In this exercise 9 and 30 men run "off scale." In this case it is more efficient to calculate the figures (19 and 14) which are inside the rule before interchanging the indices.

Chapter 4

Multiplication and Division (2)

4.1 Multiplication and Division of Three Numbers

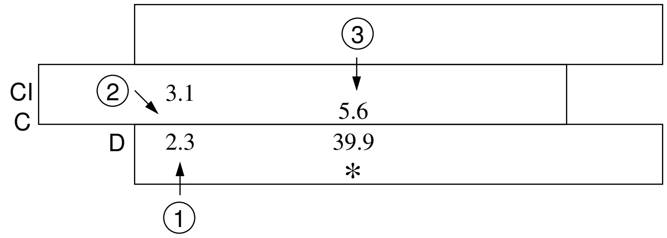
Multiplication and division of three numbers are given in the forms of $(a \times b) \times c$, $(a \times b) \div c$, $(a \div b) \times c$, and $(a \div b) \div c$. The part in parentheses is calculated in the manner previously explained and the additional multiplication or division is, usually, performed with one additional indicator operation.

FUNDAMENTAL OPERATION (5) Multiplication and division of three numbers.

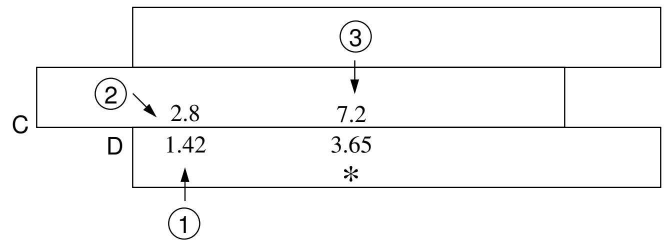
1. $\boldsymbol{(a \times b) \times c = d, (a \div b) \times c = d}$
   For additional multiplication to follow the calculation $\boldsymbol{(a \times b)}$ or $\boldsymbol{(a \div b)}$, set the hairline over the $\boldsymbol{c}$ on the C scale and read the answer $\boldsymbol{d}$ on the D scale under the hairline.
2. $\boldsymbol{(a \times b) \div c = d, (a \div b) \div c = d}$
   For additional division to follow the calculation $\boldsymbol{(a \div b)}$ or $\boldsymbol{(a \times b)}$, set the hairline over $\boldsymbol{c}$ on the CI scale and read the answer $\boldsymbol{d}$ on the D scale under the hairline.

In multiplication and division of two numbers, you use the CI scale for multiplication and the C scale for division. However, in multiplication and division of three numbers, you must use the C scale for the additional multiplication and the CI scale for the additional division.

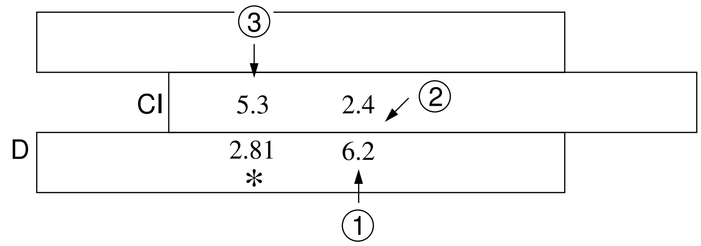
Ex. 4.1 $2.3 \times 3.1 \times 5.6 = 39.9$



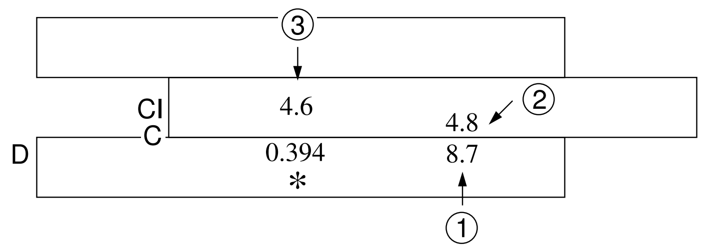
Ex. 4.2 $1.42 \div 2.8 \times 7.2 = 3.65$



Ex. 4.3 $6.2 \times 2.4 \div 5.3 = 2.81$



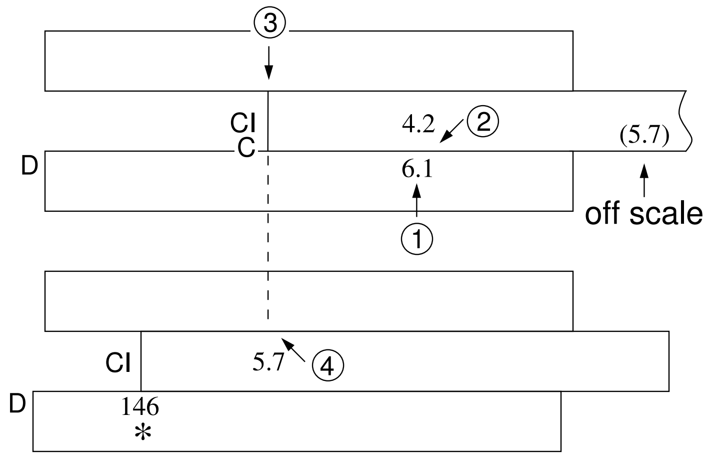
Ex. 4.4 $8.7 \div 4.8 \div 4.6 = 0.394$



4.2 Off Scale

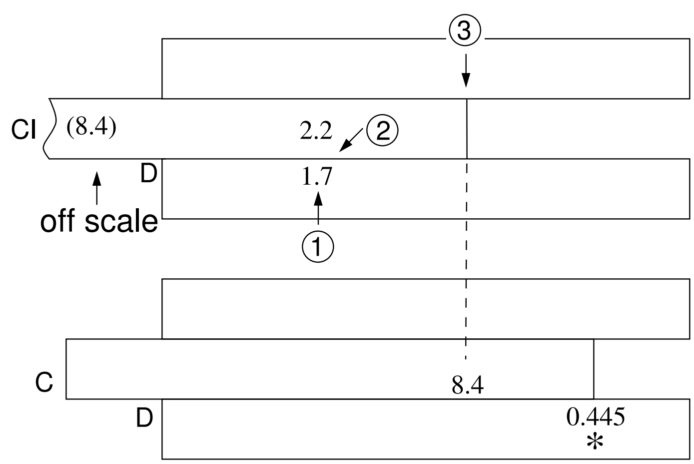
When multiplication and divisions of three numbers are performed by an indicator operation, a position on the C or CI scale over which the hairline is to be set may occasionally run off scale. In this case you once set the hairline over the position on which you read the answer of the first two numbers (opposite the index of the C scale). Then, accomplish the remaining multiplication or division by a slide operation.

Ex. 4.5 $6.1 \times 4.2 \times 5.7 = 146$



The above operations mean that the problem of $a \times b \times c = x$ is solved in such a manner as $a \times b = y$ and $y \times c = x$. Therefore, the third number 5.7 is to be set on the CI scale based on the principle of multiplication and division of two numbers. If the third operation is a division as the problem of Ex. 4.6, set the third number on the C scale.

Ex. 4.6 $1.7 \times 2.2 \div 8.4 = 0.445$

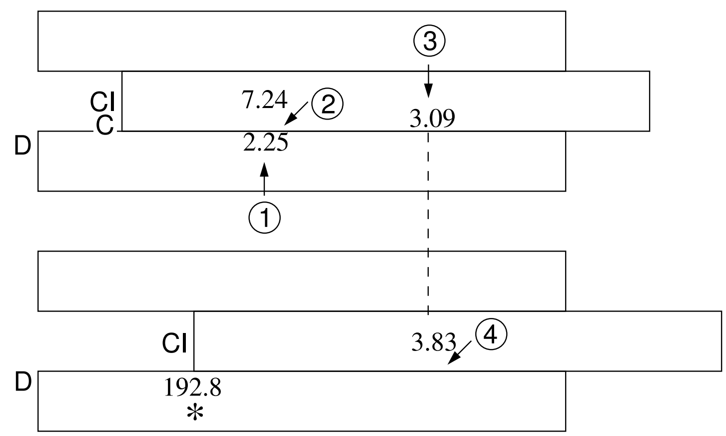


4.3 Multiplication and Division of More Than Four Numbers

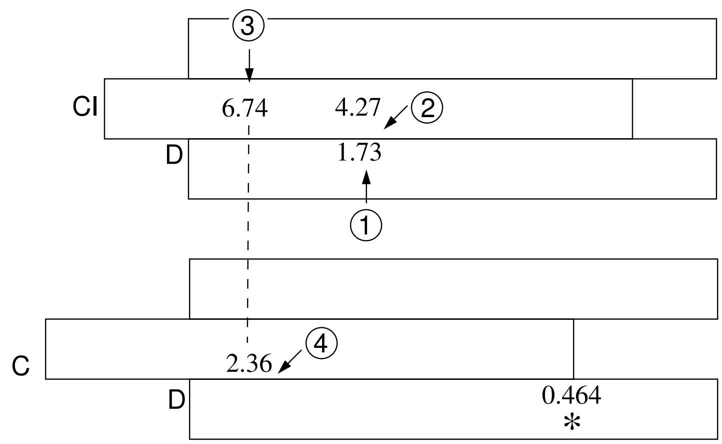
When the multiplication and division of three numbers, such as $a \times b \times c = d$ is completed, the answer (d) is found under the hairline on the D scale.

Using this value of d on the D scale you can start off further multiplications or divisions by slide operation and indicator operation. Multiplications and divisions of four or more numbers are calculated by alternative operations of slide indicator. When a problem of multiplication or division of four or more numbers is given, you will select a better procedure order of calculations to minimize the distance the slide must be moved as well as to avoid the off scale.

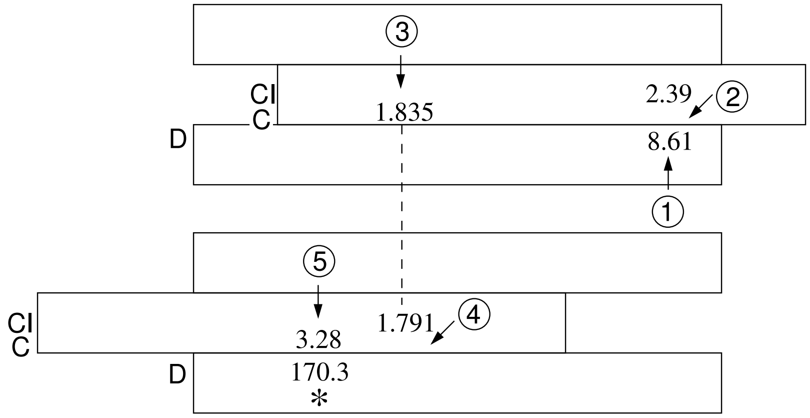
Ex. 4.7 $2.25 \times 7.24 \times 3.09 \times 3.83 = 192.8$



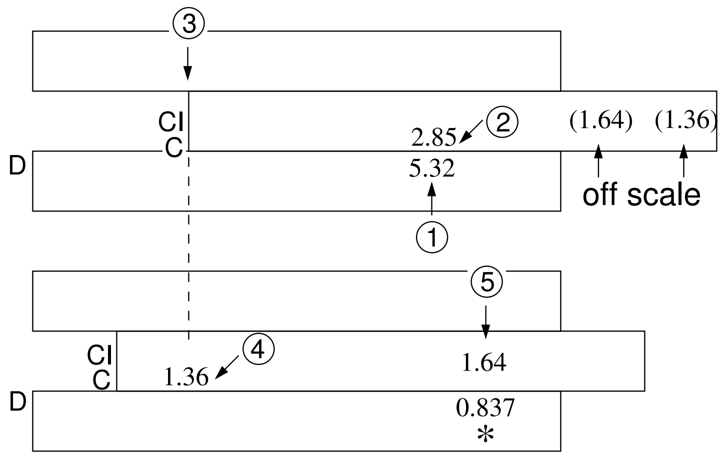
Ex. 4.8 $\dfrac{1.73 \times 4.27}{6.74 \times 2.36} = 0.464$



Ex. 4.9 $6.61 \times 2.39 \times 1.835 \times 1.791 \times 3.28 = 170.3$



Ex. 4.10 $\dfrac{5.32}{1.36 \times 1.64 \times 2.85} = 0.837$



4.4 Placing the Decimal Point

Since slide rule calculations of multiplication and division problems yield only the significant figures of the answer, it is necessary to determine the proper location of the decimal point before the problem is completed. There are many methods used to properly place the decimal point. Several of the most popular will be described here.

4.4.1 Approximation

The location of the decimal point can be determined by comparing the significant figures given by the slide rule and the product calculated mentally by rounding off.

Ex. $25.3 \times 7.15 = 810.9$

To get an approximate value $25.3 \times 7.15 \Rightarrow 30 \times 7 = 210$. Since the significant figures are read 1809 (one · eight · zero · nine) given by the slide rule, the correct answer must be 180.9.

To get an approximate value from multiplication and division of three and more factors may be difficult. In this case, the following method can be employed.

(i) Moving the decimal point

Ex. $\dfrac{285 \times 0.00875}{13.75} = 0.1814$

Divide 285 by 100 to obtain 2.85 and, at the same time, multiply 0.00875 by 100 to obtain 0.875. In other words, the decimal point of 285 is moved two places to the left and that of 0.00875 is moved two places to the right, therefore, the product of 285 times 0.00875 is not affected.

$\dfrac{285 \times 0.00875}{13.75}$ is rewritten to $\dfrac{2.85 \times 0.875}{13.75}$ and approximated to $\dfrac{3 \times 0.9}{10} = 0.27.$

Since you read 1814 (one eight one four) on the slide rule, the answer must be 0.1814.

Ex. $\dfrac{1.346}{0.00265} = 508$

$$\frac{1.346}{0.00265} \Rightarrow \frac{1346}{2.65} \Rightarrow \frac{1000}{3} \Rightarrow 300$$

(ii)Reducing fractions

If a number in the numerator has a value close to that of a number in the denominator, they can be cancelled out and an approximate figure is obtained.

Ex. $\dfrac{1.472 \text{ x } 9.68 \text{ x } 4.76}{1.509 \text{ x } 2.87} = 15.66$

$$\frac{\cancel{1.472} \text{ x } \overset{3}{\cancel{9.68}} \text{ x } 4.76}{\cancel{1.509} \text{ x } \cancel{2.87}}$$

1.472 in the numerator can be considered to be equal to 1.509 in the denominator and they can therefore be cancelled out. 9.68 in the numerator is approximately 9 and 2.87 in the denominator is approximately 3. 4.76 in the numerator is approximately 5. Using the slide rule, you read 1566 on the D scale, therefore, the answer must be 15.66.

Combination of (ii) and (iii)

Ex. $\dfrac{7.66 \times 0.423 \times 12.70}{0.641 \times 3.89} = 16.50$

$$\frac{7.66 \text{ x } 0.423 \text{ x } 1.70}{0.641 \text{ x } 3.89} \rightarrow \frac{\cancel{7.66} \text{ x } \cancel{4.23} \text{ x } 1.70}{\cancel{6.41} \text{ x } \cancel{3.89}} \rightarrow 13$$

The decimal point of 0.423 and 0.641 in the numerator is shifted one place to the right. The approximate numbers in the denominator and numerator are cancelled and the answer, which is approximately 13, is found.

4.4.2 Exponent

Any number can be expressed as $N \times 10^P$ where $1 \leq N < 10$. This method of writing numbers is useful in determining the location of the decimal point in difficult problems involving combined operations.

Ex.

$$\begin{aligned}
\frac{1587 \times 0.0503 \times 0.381}{0.00815} &= 3730 \\
\frac{1587 \times 0.0503 \times 0.381}{0.00815} &= \frac{1.587 \times 10^3 \times 5.03 \times 10^{-2} \times 3.81 \times 10^{-1}}{8.15 \times 10^{-3}} \\
&= \frac{1.587 \times 5.03 \times 3.81}{8.15} \times 10^{3-2-1-(-3)} \\
&= \frac{2 \times 5 \times 4}{8} \times 10^{3-2-1-(-3)} \\
&= 5 \times 10^3 \\
&= 5000
\end{aligned}$$

Chapter 5

Squares and Square Roots

The "place number" is used to find squares and square roots as well as placing the decimal point of squares and square roots.

When the given number is greater than 1, the place number is the number of digits to the left of the decimal point. When the given number is smaller than 1, the place number is the number of zeros between the decimal point and the first significant digit but the sign is minus.

For example, the place number of 2.97 is 1, of 29.7 is 2, of 2970 is 4, and of 0.0297 is -1. The place number of 0.297 is 0.

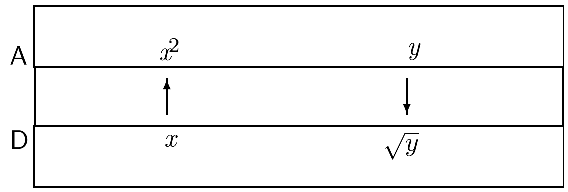
5.1 Squares and Square Roots

The A scale, which is identical to the B scale, consists of two D scales connected together and reduced to exactly 1/2 of their original length. The A scale is used with the C, D or CI scale to perform the calculations of the square and square root of numbers.

Since they consist of two D scales, the A and B scales are called "two cycle" scales whereas the fundamental C, D and CI scales are called "one cycle scales."

FUNDAMENTAL OPERATION (6) $\boldsymbol{x^2}, \sqrt{\boldsymbol{y}}$

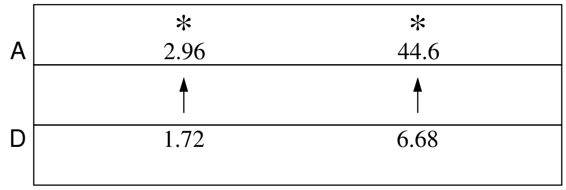
1. When the hairline is set over $\boldsymbol{x}$ on the D scale, $\boldsymbol{x^2}$ is read on the A scale under the hairline.
2. When the hairline is set over $\boldsymbol{y}$ on the A scale, $\sqrt{\boldsymbol{y}}$ is read on the D scale under the hairline.



The location of the decimal point of the square read on the A scale is determined using the place number as follows:

- When the answer is read on the left half section of the A scale ($1 \sim 10$), the "place number" of $x^2 = 2$ ("place number" of x) $- 1$
- When the answer is read on the right half section of the A scale ($10 \sim 100$), the "place number" of $x^2 = 2$ ("place number" of x)

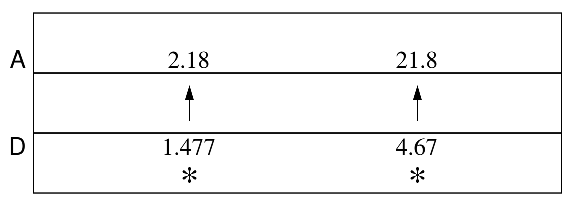
Ex. 5.1	$172^2 = 29600$	The place number of 172 is 3. Hence, the place number in the answer is $2 \times 3 - 1 = 5$
	$17.2^2 = 296$	The place number of 17.2 is 2. Hence, the place number in the answer is $2 \times 2 - 1 = 3$
	$0.172^2 = 0.0296$	The place number of 0.172 is 0. Hence, the place number in the answer is $2 \times 0 - 1 = -1$
Ex. 5.2	$668^2 = 446000$ .... $= 4.46 \times 10^5$	The place number of 668 is 3. Hence, the place number in the answer is $2 \times 3 = 6$
	$0.668^2 = 0.446$	The place number of 0.668 is 3. Hence, the place number in the answer is $2 \times 0 = 0$
	$0.0668^2 = 0.00446$	The place number of 0.0688 is -1. Hence, the place number in the answer is $2 \times (-1) = -2$



When the hairline is set over x on the A scale, $\sqrt{x}$ appears under the hairline on the D scale. Since the A scale consists of two identical sections, only the correct section can be used. Set off the number whose square root is to be found into two digit groups from the decimal point toward the first significant figure of the number. If the group in which the first significant figure appears has only one digit (the first significant digit only), use the left half of the A scale. If it has two digits (the first significant digit and one more digit), use the right half of the A scale.

Ex. 5.3

$21|80|00$ (right half) Place number . . . . . . 3 $\sqrt{218000} = 467$
$2|18|00$ (left half) Place number . . . . . . 3 $\sqrt{21800} = 147.7$
$21|80$ (right half) Place number . . . . . . 2 $\sqrt{2180} = 46.7$
$2|18$ (left half) Place number . . . . . . 2 $\sqrt{218} = 14.77$
$0.21|8$ (right half) Place number . . . . . . 0 $\sqrt{0.218} = 0.467$
$0.02|18$ (left half) Place number . . . . . . 0 $\sqrt{0.0218} = 0.1477$
$0.00|21|8$ (right half) Place number . . . . . . 1 $\sqrt{0.00218} = 0.0467$
$0.00|02|18$ (left half) Place number . . . . . . 1 $\sqrt{0.000218} = 0.01477$



5.2 Multiplication and Division Involving the Square and Square Root of Numbers

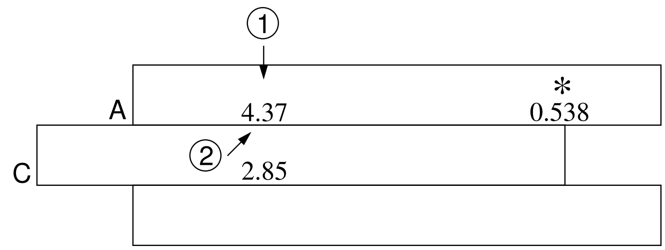
Basically, the A scale is the same logarithm scales as the D scale. Therefore, you can use the A, B, and BI scales for multiplication and division in the same manner as you use the C, D and CI scales.

FUNDAMENTAL OPERATION (7)
MULTIPLICATION AND DIVISION INVOLVING SQUARES.

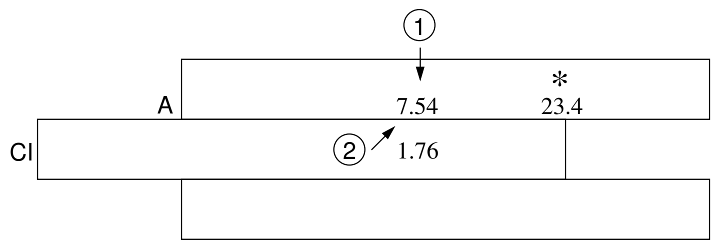
1. Set the number to be squared on the one cycle scale (C, D, or CI) and the number not to be squared on the two cycle scale (A, B, or BI).

2. Read the answer on the A scale.

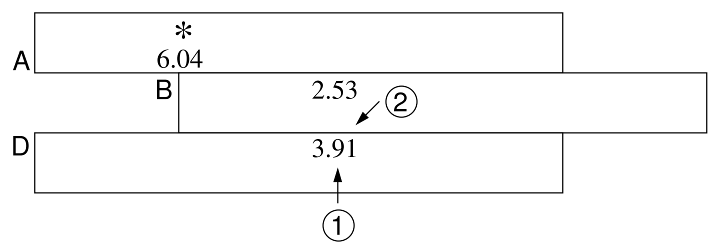
Ex. 5.4 $4.37 \div 2.85^2 = 0.538$



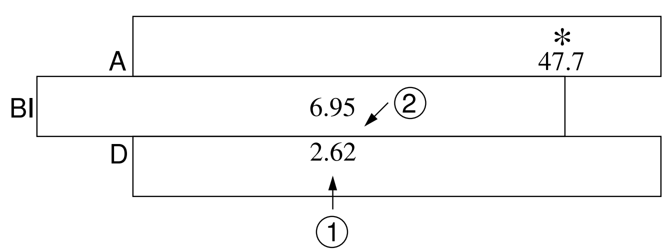
Ex. 5.5 $7.54 \times 1.76^2 = 23.4$



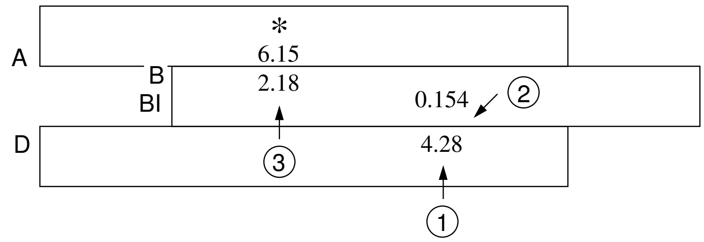
Ex. 5.6 $3.91^2 \div 2.53 = 6.04$



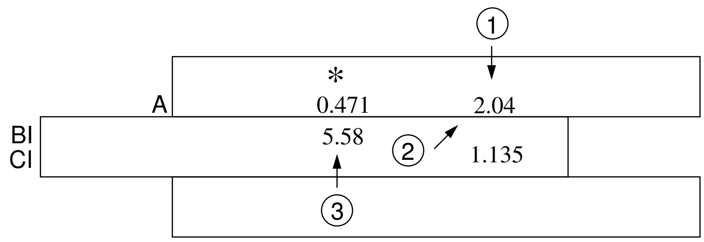
Ex. 5.7 $2.62^2 \times 6.95 = 47.7$



Ex. 5.8 $4.28^2 \times 0.154 \times 2.18 = 6.15$



Ex. 5.9 $\dfrac{2.04 \times 1.135^2}{5.58} = 0.471$



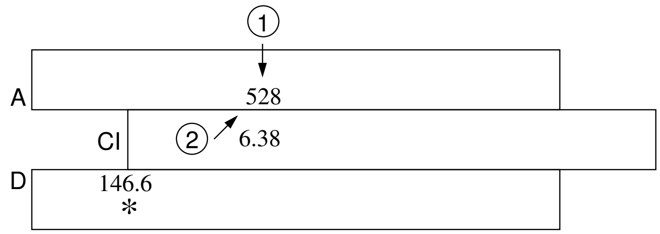
If the hairline is set over 2.04 on the left half of the A scale, the slide will extremely protrude to the left from the slide rule when setting 1.135 on the CI scale under the hairline. Therefore, set the hairline over 2.04 on the right half of the A scale disregarding the place number of the reading. In multiplication or division involving squares you can freely use either half section of the A, B or BI scale to minimize the distance the slide must be moved.

FUNDAMENTAL OPERATION (8)
MULTIPLICATION AND DIVISION INVOLVING SQUARE ROOTS.

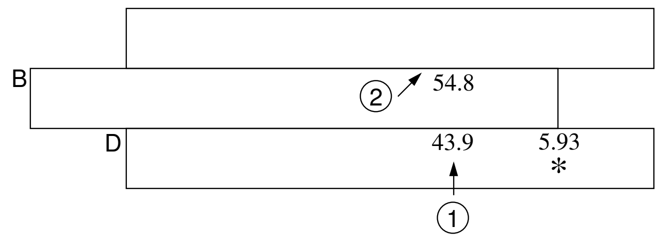
1. Set the number to be square rooted on the two cycle scales (A, B, or BI) and the number not to be square rooted on the one cycle scales (C, D or CI).
2. Read the answer on the D scale.

In multiplication and division which involves the square roots of numbers, the correct section of the A, B or BI scale must be used. The correct section of the A, B or BI scale to be used can be determined in the manner previously described.

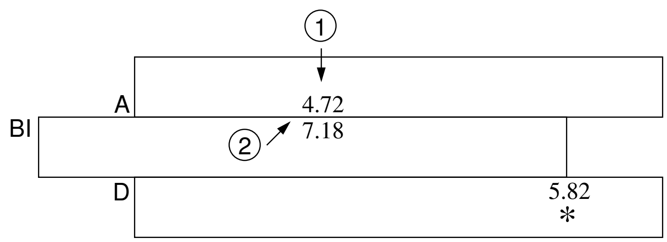
Ex. 5.10 $\sqrt{528} \times 6.38 = 146.6$



Ex. 5.11 $439 \div \sqrt{54.8} = 5.93$

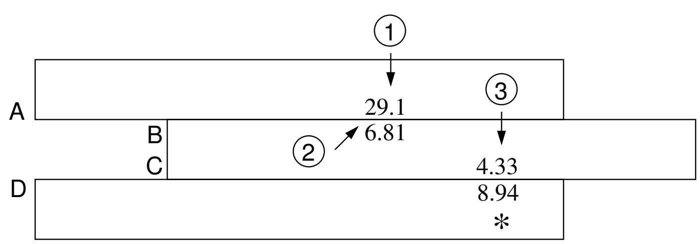


Ex. 5.12 $\sqrt{4.72 \times 7.18} = 5.82$

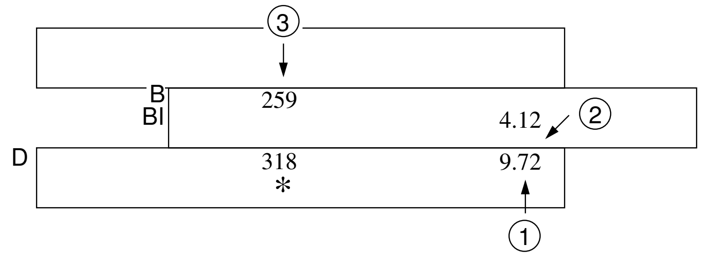


In Ex. 5.12, $\sqrt{4.72 \times 7.18}$ can be broken into the form $\sqrt{4.72} \times \sqrt{7.18}$. Therefore, both numbers are set on the two cycle scales.

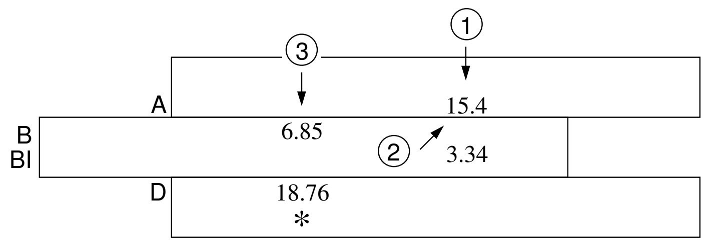
Ex. 5.13 $\dfrac{\sqrt{29.1} \times 4.33}{\sqrt{6.81}} = 8.94$



Ex. 5.14 $9.72 \times \sqrt{4.12} \times \sqrt{259} = 318$



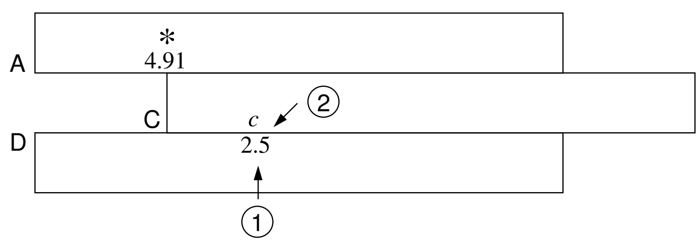
Ex. 5.15 $\sqrt{15.4 \times 3.34 \times 6.85} = 18.76$



5.3 The Area Of a Circle

A gauge mark "*c*" is imprinted on the C scale at the 1.128 position. This is used with the D scale to find the area of a circle.
(Note) The No. 135 has no gauge mark "*c*."

Ex. 5.16 Find the area of a circle having a diameter of 2.5cm.



Answer 4.91 cm^2

Chapter 6

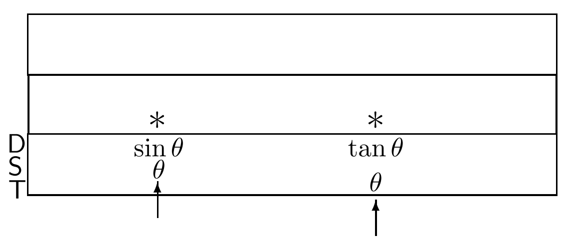
Trigonometric Functions

The S scale is used to find $\sin\theta$ and the T scale to find $\tan\theta$. Angles are given in degrees and decimals of degrees. The angles are shown in black and their complementary angles are in red, adjoining each other.

6.1 Sine, Tangent, Cosine

FUNDAMENTAL OPERATION (9) $\sin\theta, \tan\theta$

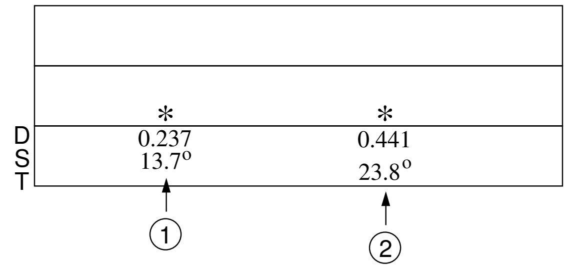
1. When the hairline is set over θ on the S scale, $\sin\theta$ appears on the D scale.
2. When the hairline is set over θ on the T scale, $\tan\theta$ appears on the D scale.



Angles are read on the T and S scales according to the black numbers.

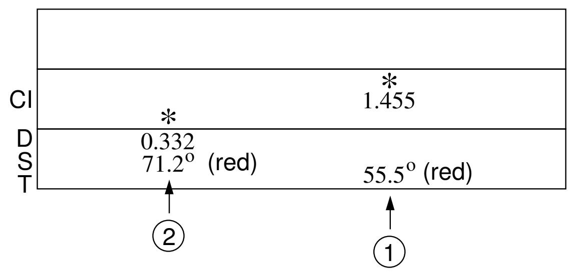
Ex. 6.1 (1) $\sin 13.7° = 0.237$ (2) $\tan 23.8° = 0.441$

The T scale is graduated from left to right from approximately 6° to 45°, and from right to left from 45° to approximately 84°.



The angles from left to right are shown by the black numbers and from right to left shown by the red numbers. Therefore, to obtain the value of $\tan\theta$ which larger than 45°, use the red numbers on the T scale. In this case, the answer is found on the CI scale.

Ex. 6.2 (1) $\tan 55.7° = 1.455$ (2) $\cos 71.2° = 0.322$



Cot $\theta, \sec\theta$, cosec θ are found as reciprocals of $\tan\theta, \cos\theta$ and $\sin\theta$, respectively. Since a value under the hairline on the D (or C) scale is the reciprocal of the value under the hairline on the DI scale, this relationship is conveniently used.

* Very small angles:

For very small angles, the sine function, tangent function, and the angle in radians are very nearly equal.

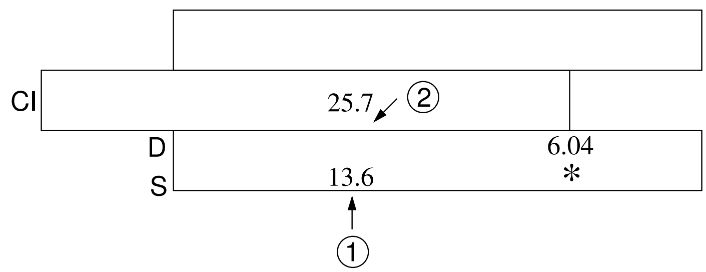
1 radian is equal to 57.29° and is indicated by the R gauge mark on the C scale.

6.2 Multiplication and Division Involving Trigonometric Functions

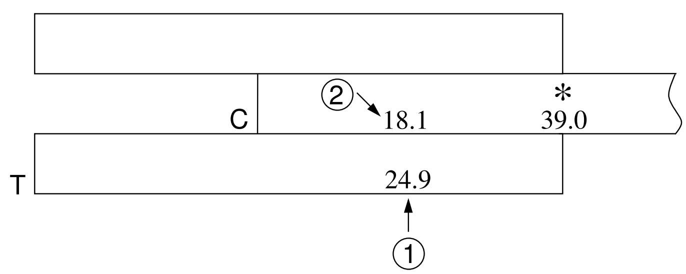
Multiplication and division involving trigonometric functions can be calculated by using the C and CI scales cooperated with trigonometric scales of S and T.

As explained in the foregoing article, when the hairline is set over the angle on the S scale, the sine of the angle ($\sin\theta$) is found on the D scale under the hairline. Therefore, a number on the CI scale is moved to set over the hairline, and multiplication $a \times \sin\theta$ can be performed. The answer is found on the D scale opposite the index of the CI scale. Multiplication or division involving the tangent function can be calculated by using the T scale. When the angle is larger than 45°, set the hairline over the S or T scale using the red numbers which are numbered from right to left. In this case, read the sine or tangent of the angle on the CI scale and re-set the read sine or tangent on the D scale and continue the calculation by moving the slide to bring a number on the C or CI scale to the hairline. The answer also appears the D scale.

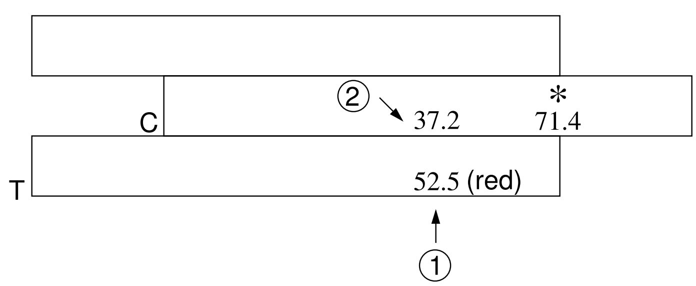
Ex. 6.3 $25.7 \times \sin 13.6° = 6.04$



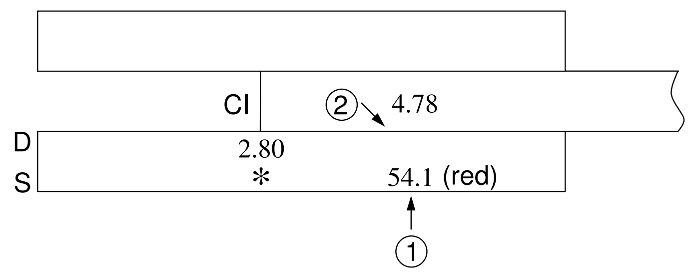
Ex. 6.4 $18.1 \div \tan 24.9° = 39.0$



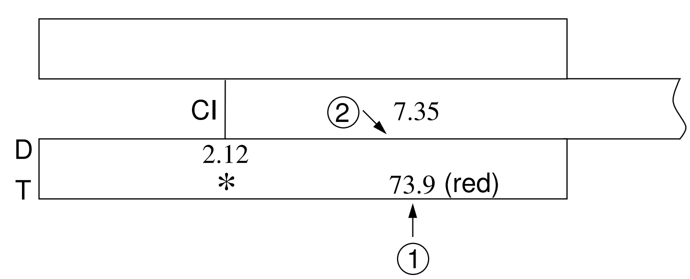
Ex. 6.5 $37.2 \times \tan 62.5° = 71.4$



Ex. 6.6 $4.78 \times \cos 54.1° = 2.80$



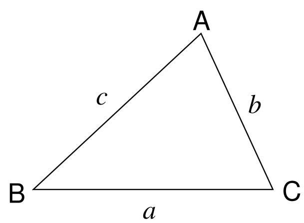
Ex. 6.7 $7.35 \times \cot 73.9° = 2.12$



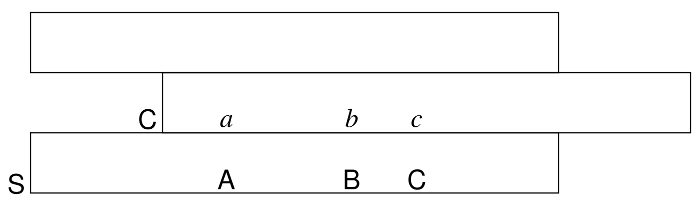
6.3 Solution of Triangles by Use of the Law of Sines

FUNDAMENTAL OPERATION (10) The law of sines.
The following formula can be established from the relationship of any given angle: A, B, and C are the angles and a, b, and c are the corresponding sides.

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

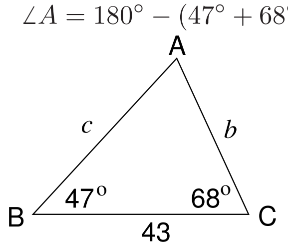


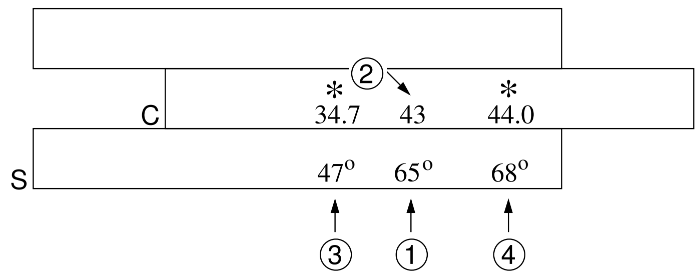
When the known angle and its corresponding side are set on the S and C scales, the unknown side (or angle) corresponding to the known angle (or side) can be found by indicator operation.



Ex. 6.8 Find b and c,

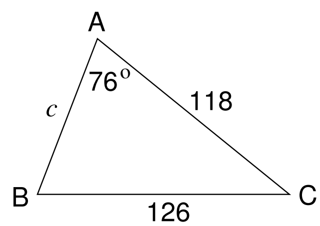
$$\angle A = 180° - (47° + 68°) = 65°$$



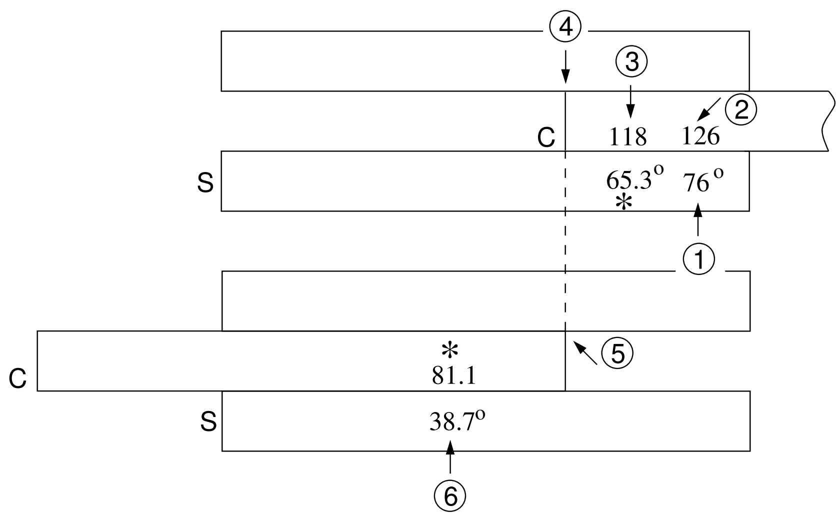


Answer $b = 34.6, c = 44.0$

Ex. 6.9 Find $\angle B$ and $\angle C$ and c.

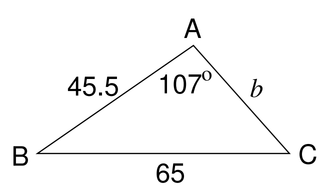


$\angle C = 180° - (76° + 65.3°) = 38.7°$



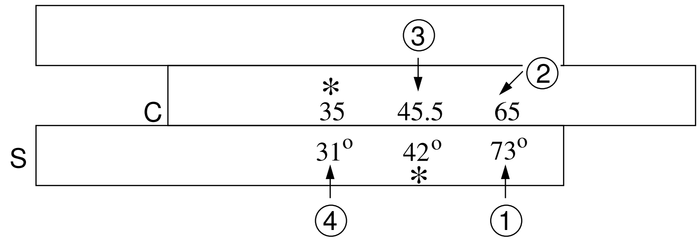
Answer $\angle B = 65.3°, \angle C = 38.7°, c = 81.1$

Ex. 6.10 Find $\angle B$ and $\angle C$ and b.



If the angle is larger than 90°, set 73° ($180° - 107° = 73°$) and 65° on the S and C scales, basing on $\sin\theta = \sin(180° - \theta)$

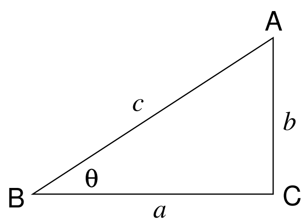
$\angle B = 73° - 42° = 31°$.



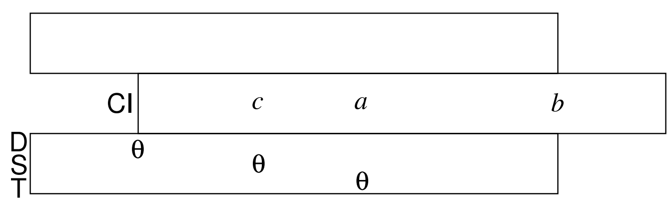
Answer $\angle B = 31°, \angle C = 42°, b = 35$

6.4 Solution of a Right Triangle

FUNDAMENTAL OPERATION (11) Right Triangle.

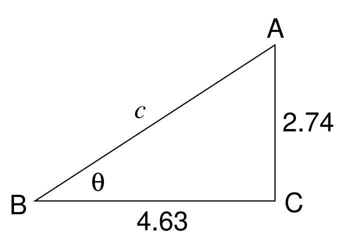


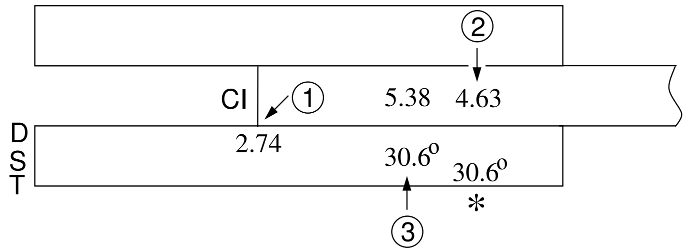
The right triangle is solved by using the D, CI, S, and T scales in the manner as illustrated below.



Right triangle, vector, and complex number calculations can be easily performed by utilizing this relationship.

Ex. 6.11 Find c and θ.

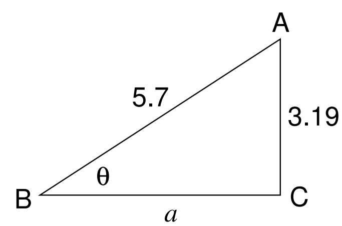


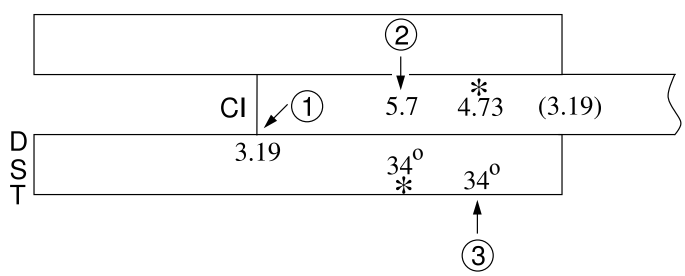


Answer $c = 5.38, \theta = 30.6°$

(Note) $\sqrt{2.74^2 + 4.63^2} = 5.38$ can be performed in the same manner as in the above example. In this case, θ is called "parameter."

Ex. 6.12 Find θ and a.



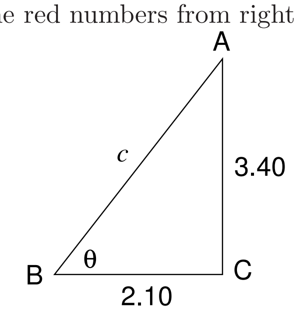


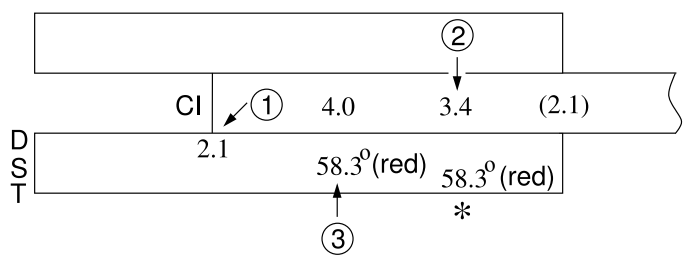
Answer $a = 4.73, \theta = 34°$

(Note) The same operation can be employed in the problem $\sqrt{5.7^2 - 3.19^2} =$ 4.73

Ex. 6.13 Convert $2.10 + 3.40i$ to polar coordinates.

This problem is an application to solve the right triangle to find θ and the oblique side c, when the bottom side is 2.10 and the vertical side is 3.40. If θ is larger than 45°, rotate the right triangle 90° and perform calculation considering the bottom side as b and the vertical side as a. The answer falls on either S and T scale, but in this case the trigonometric scale is read using the red numbers from right to left.

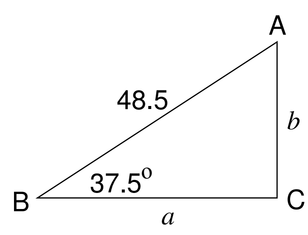


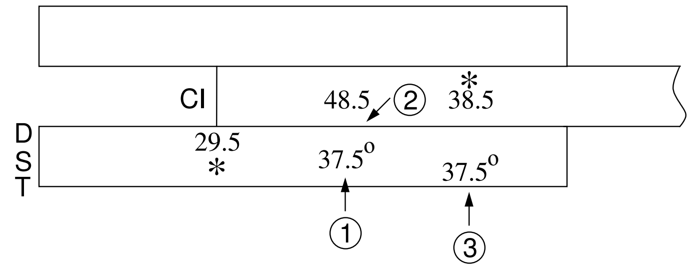


Answer $2.10 + 3.40i = 4.00\angle 58.3°$

Ex. 6.14 Convert $48.5\angle 37.5°$ to rectangular coordinates.

This problem is the application to find the bottom side a and vertical side b of the right triangle shown at the right





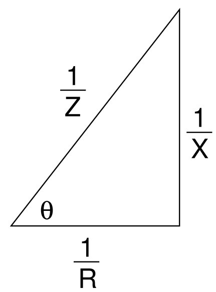
Answer $48.5\angle 37.5° = 38.5 + 29.5i$

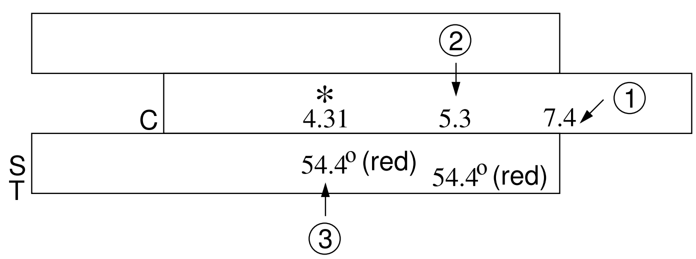
Ex. 6.15 Find the combined impedance Z and phase difference when resistance $R = 7.4$ kΩ and the induction reactance $x = 5.3$ kΩ are connected in parallel.

(SOLUTION) R and X connected in parallel can be shown in the formula below.

$$Z = \frac{1}{\sqrt{\frac{1}{R^2} + \frac{1}{X^2}}} = \tan^{-1}\frac{1/X}{1/R} = \tan^{-1}\frac{R}{X}$$

Thus, this is the same as solving the problem of the right triangle illustrated at the right. Calculation can be easily performed by utilizing the reciprocal relationship of the CI and C scales.





Answer $Z = 4.31$ kΩ$, \theta = 54.4°$

Chapter 7

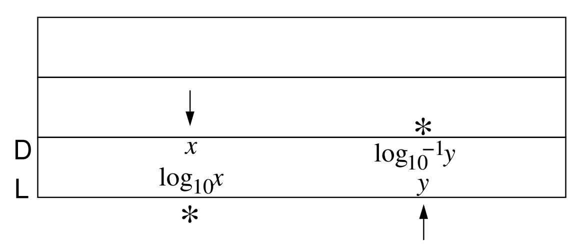
Logarithm. Decibel.

7.1 Common Logarithm

The L scale is graduated $1 \sim 10$ and used to find the mantissa (the decimal part) of common logarithms cooperated with the D scale. The characteristic is, this, determined. When the place number of the given number is m, characteristic of the logarithm is $m - 1$.

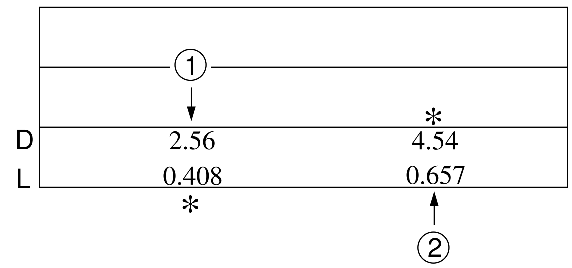
FUNDAMENTAL OPERATION (12) $\log_{10} x$ and antilog$_{10}y(10^y)$

1. Set the hairline over x on the D scale, $\log_{10} x$ can then be found on the L scale.
2. Set the hairline over y on the L scale, antilog$_{10}y$ can then be found on the D scale.



Ex. 7.1

(1)	$\log_{10} 2.56$	=	0.408	(2)	antilog$_{10}$ 0.657	=	4.54
	$\log_{10} 256$	=	2.408		antilog$_{10}$ 1.657	=	45.4
	$\log_{10} 0.0256$	=	$\bar{2}.408$		antilog$_{10}$ $\bar{1}.657$	=	0.454

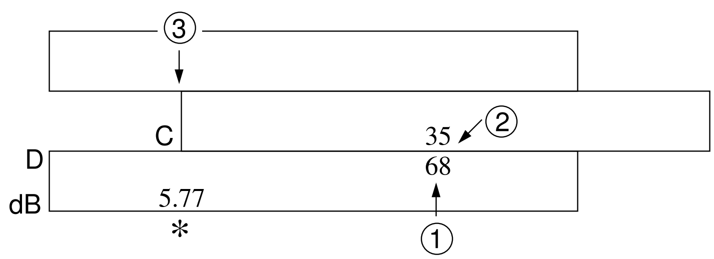


In ex. 7.1, $\log_{10} 0.0256$ is found $\overline{2}.408$. However, this form of $\overline{2}.408$ is, since the characteristic is a minus number and the mantissa is a plus number, not suitable for further continuous calculation. Therefore, in such a case, $\overline{2}.408$ should be rewritten to the form of $-2 + 0.408 = -1.592$, which is a common number and makes further calculation possible.

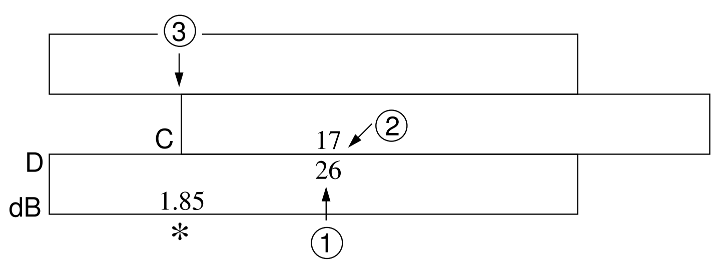
7.2 Decibel

The dB scale is the same as the L scale and is used to find $\log_{10} x$ (the red part) and 20 $\log_{10} x$ (the black part) corresponding to x on the D scale.

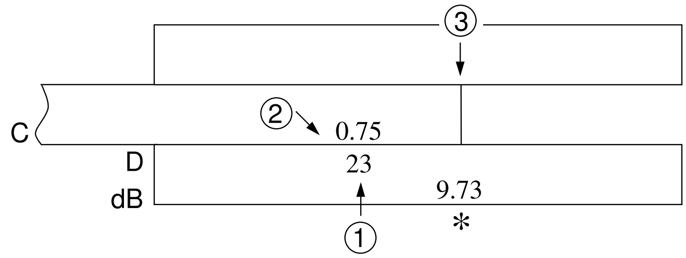
Ex. 7.2 Find the voltage in decibel, (dB) $= 20 \log_{10} \frac{V_2}{V_1}$, when input voltage $V_1 = 35$ mV and output voltage $V_2 = 68$ mV. (5.77 dB)



Ex. 7.3 Find the power loss between input power $P_1 = 26$ W and the power $P_2 = 17$ W using decibel (dB) $= 10 \log_{10} \frac{P_2}{P_1}$ If P_1 is larger than P_2, calculate P_1/P_2 with the C and D scales, and affix a minus sign to the decibel value obtained. (-1.85 dB)



Ex. 7.4 Find the power loss between input voltage $V_1 = 23$ V and output voltage $V_2 = 0.75$ W using decibel (dB) $= 20 \log_{10} \frac{V_2}{V_1}$ (-29.73 dB)



If V_2/V_1 are between $0.1 \sim 0.01$, dB will be between $-20 \sim -40$. -9.73 can be found through the above illustration. Read the answer after -20 is added to it.

Chapter 8

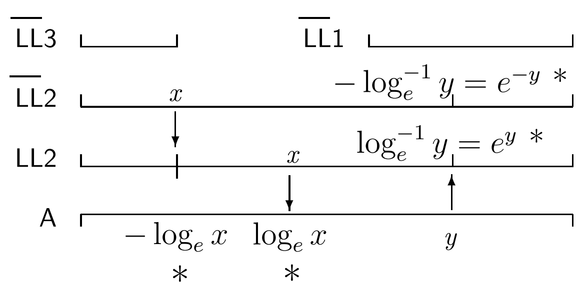
Exponents

The LL scale (LL2) is called a log log scale and ranges from 1.11 to 20,000. The LL/ scale (LL/1, LL/2, LL/3) is also a log log scale, but is for the decimals, and ranges from 0.99 to 10^{-9}. Both the LL and LL/ scales correspond to the A scale to calculate exponents and are read with the decimal point.

8.1 How to Find Natural Logarithms

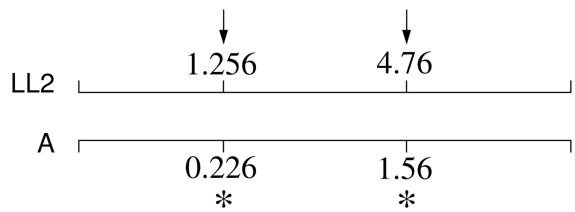
FUNDAMENTAL OPERATION (13) $\log_e x$, e^y

1. Set the hairline over x on the LL scale, and find $\log_e x$ on the A scale.
2. Set the hairline over y on the A scale, and find $\log_e^{-1} y = e^y$



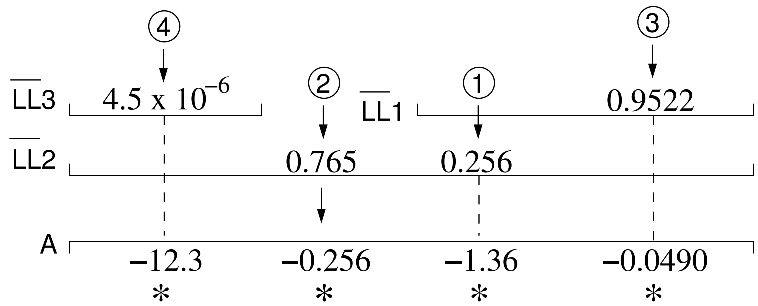
Ex. 8.1

$\log_e 4.76 = 1.56$ read the A scale at the range of $1 \sim 10$
$\log_e 1.256 = 0.228$ read the A scale at the range of $0.1 \sim 1$.



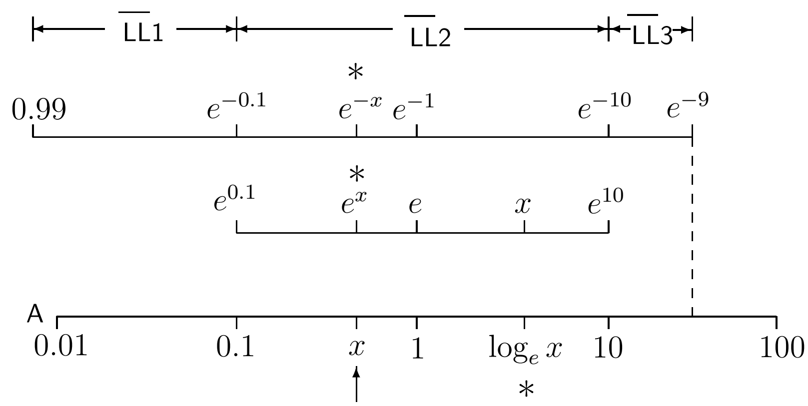
Ex. 8.2

(1) $\log_e 0.256 = -1.36$ (3) $\log_e 0.9522 = -0.0490$
(2) $\log_e 0.765 = -0.268$ (4) $\log_e 4.5 \times 10^{-6} = -12.3$



(Note) The A scale of this rule consists of two identical sections: 1 – 10 and 10 – 100, totally covering the calculation range from 1 – 100. The range of calculation covered, however, can also be considered 0.01 – 0.1 and 0.1 – 1, completely from 0.01 – 1 according to how the decimal point is located. The relationship between the label number of the LL scale and the range covered by the A scale is as follows.

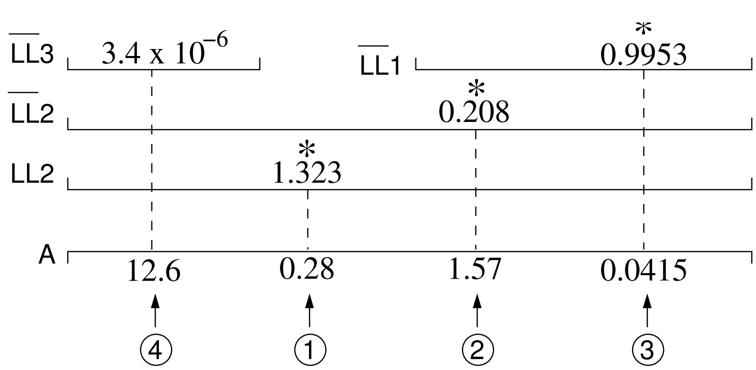
LL/1	0.01 – 0.1	of the A scale
LL/2 and LL2	0.1 – 10	of the A scale
LL/3	10 – 20.6	of the A scale



Ex. 8.3

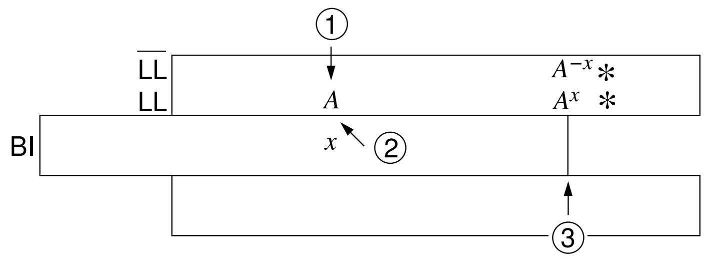
(1)$e^{0.28} = 1.323$ (3)$e^{-0.0415} = 0.9593$
(2)$e^{-1.57} = 0.208$ (4)$e^{-12.6} = 3.4 \times 10^{-6}$

Set the hairline over x on the A scale, e^x can then be found on the LL scale and e^{-x} on the $\overline{\text{LL}}$ scale.

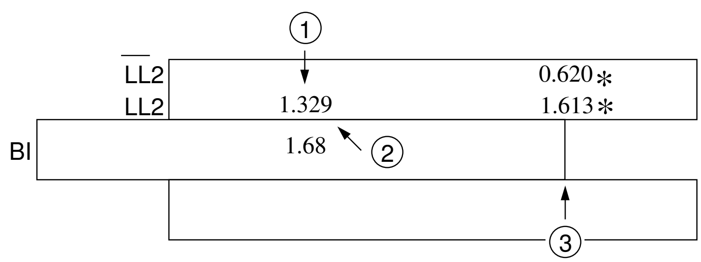


FUNDAMENTAL OPERATION (14) A^x, A^{-x}, $(A > 1)$

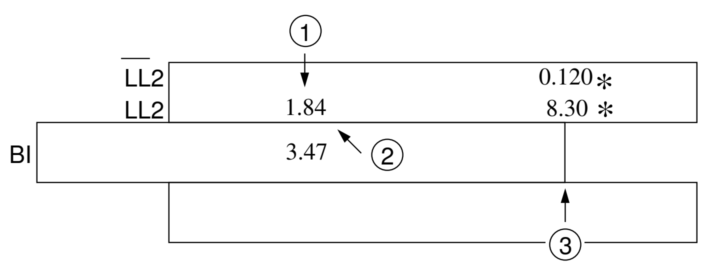
1. Set the hairline over A on the LL scale.
2. Move x on the BI scale to the hairline. Read the answer on the LL scale under the hairline in the case of A^x, and on the $\overline{\text{LL}}$ scale under the hairline in the case of A^{-x}.



Ex. 8.4 $1.329^{1.68} = 1.613$ $1.329^{-1.68} = 0.620$

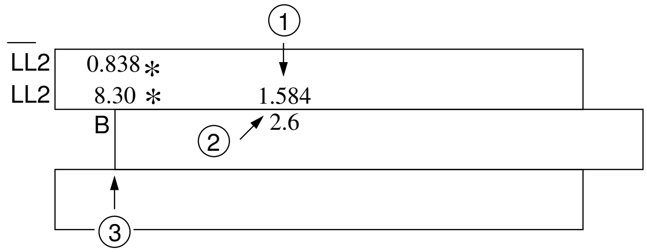


Ex. 8.5 $1.84^{3.47} = 8.30$ $1.84^{-3.47} = 0.120$

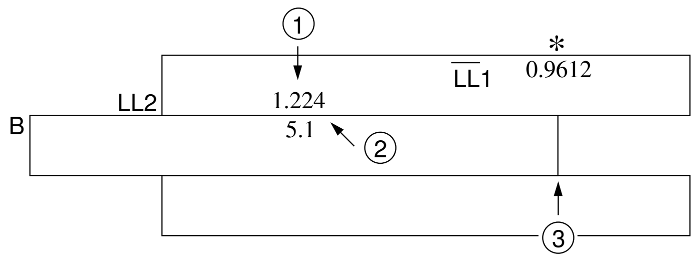


The B scale can be used instead of the BI scale to calculate A.

Ex. 8.6 $1.584^{\frac{1}{2.6}} = 1.194 \quad 1.584^{-\frac{1}{2.6}} = 0.838$



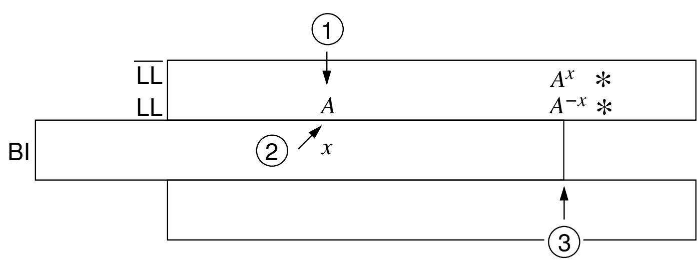
Ex. 8.7 $1.224^{-\frac{1}{5.1}} = 8.30$



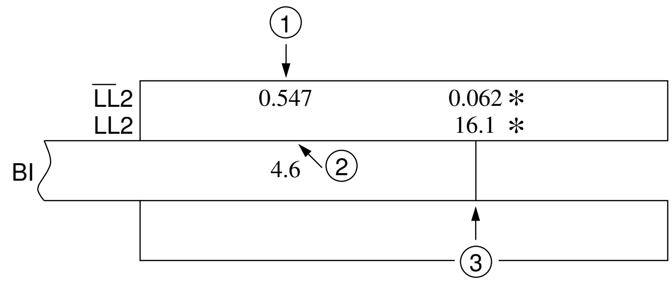
The answer will be on the $\overline{\text{LL}}$ scale opposite the left index, and is equivalent to $\overline{\text{LL}}1$. Therefore, read the value on $\overline{\text{LL}}1$ opposite the right index.

FUNDAMENTAL OPERATION (15) $A^x,\ A^{-x},\ (A < 1)$

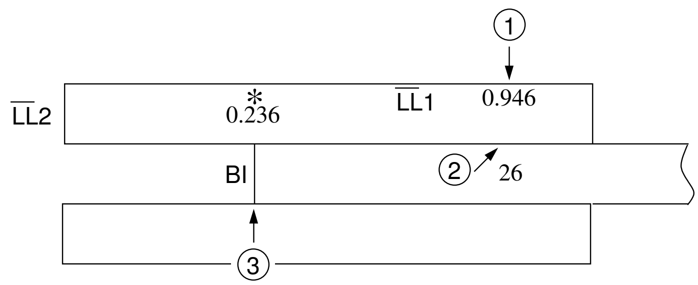
1. Set the hairline over A on the $\overline{\text{LL}}$ scale.
2. Move x on the BI scale under the hairline. The answer can be found on the $\overline{\text{LL}}$ scale under the hairline in the case of A^x, and on the LL scale under the hairline in the case of A^{-x}.



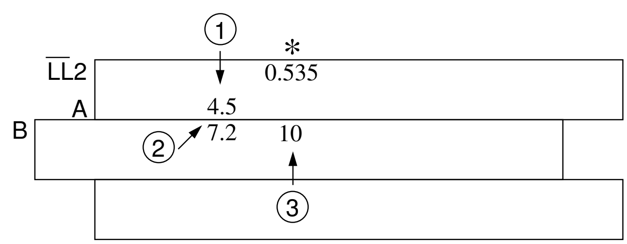
Ex. 8.8 $0.547^{4.6} = 0.062$



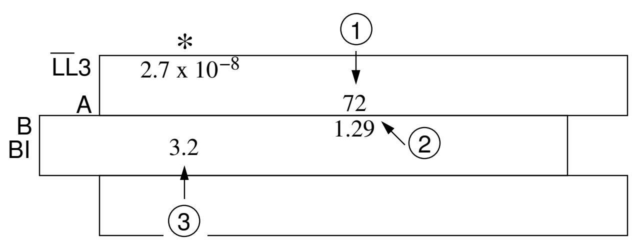
Ex. 8.9 $0.946^{26} = 0.236 \quad (0.946^{2.6\times 10})$



Ex. 8.10 $e^{-\frac{4.5}{7.2}} = 0.535$

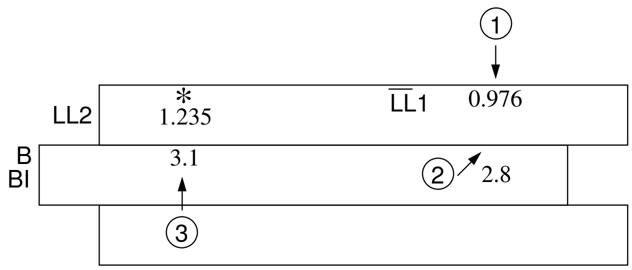


Ex. 8.11 $e^{-\frac{7.2}{1.29\times 3.2}} = 2.7 \times 10^{-8}$



$-\dfrac{72}{1.29 \times 3.2}$ is known to be between $-10 \sim -100$ by mental calculation; therefore, "off scale" does not occur if the $\overline{\text{LL}}3$ scale is used, assuming that the answer will appear on the the $\overline{\text{LL}}3$ scale.

Ex. 8.12 $0.976^{-2.8\times 3.1} = 1.235$



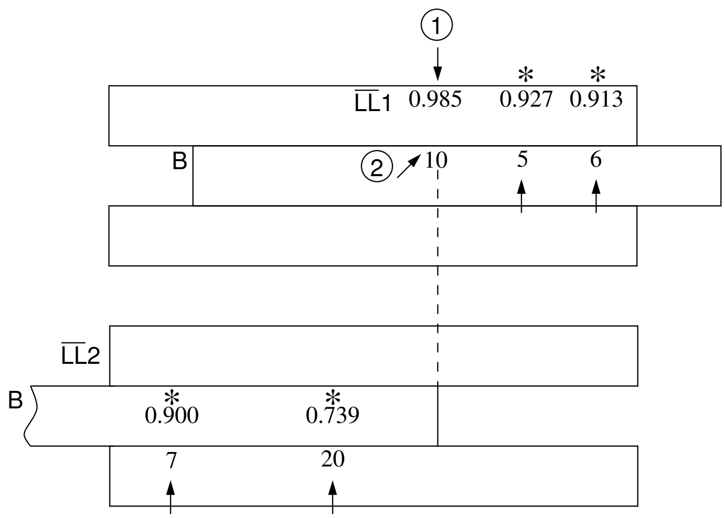
Since 2.8×3.1 is found to be approximately 9 by mental calculation, operate the rule in the manner illustrated above presuming that the answer will appear on the left half of the LL2 scale (the part which corresponds to the left part of the A scale).

Ex. 8.13 Considering that an average available percentage for one process is 98.5%, what average available percentage will there be after $5, 6, 7$ and 20 processes?

$0.985^5 = 0.927$ $\qquad 0.985^6 = 0.913$

$0.985^7 = 0.900$ $\qquad 0.985^{2}0 = 0.739$

In the formula $y = x^m$ when the value of m varies (x is constant), perform the operation in the following manner: set the index of the B scale over x on the LL scale, move the hairline to m on the B scale, and find the value on the LL scale under the hairline. This minimizes the slide movements.

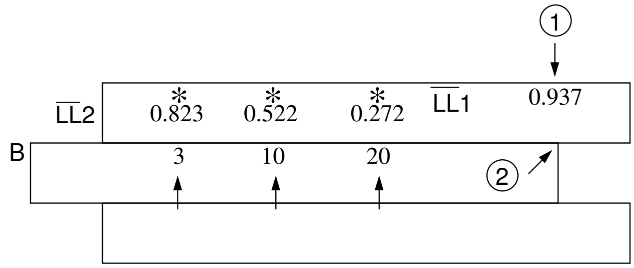


Ex. 8.14 $\quad 1.067^3 = 1.215,\ 1.067^{1}0 = 1.915,\ 1.067^{2}0 = 3.68$

The graduations on the LL scale only from 1.11 to 20,000. Therefore, 1.067 is calculated in the following manner.

Convert $\dfrac{1}{\left(\dfrac{1}{1.067}\right)^m}$ and find $1/1.067 = 0.937$ with the CI and C scales. Then find $0.937^3 = 0.823,\ 0.937^{10} = 0.522$ and $0.927^{20} = 0.272$ with the LL and

B scales, and again find $1/0.823 = 1.215$, $1/0.522 = 1.915$ and $1/0.272 = 3.68$ with the CI and C scales.



As shown in the above example, when a reciprocal must be found during calculation, it is important to calculate as carefully as possible on the assumption that the chances of error are growing comparitively larger.

This example shows calculation of compound interest (at 6.7% annual interest).

8.2 Hyperbolic Functions

Calculations involving hyperbolic functions are often used in the study of alternating current theory and long power transmission lines.

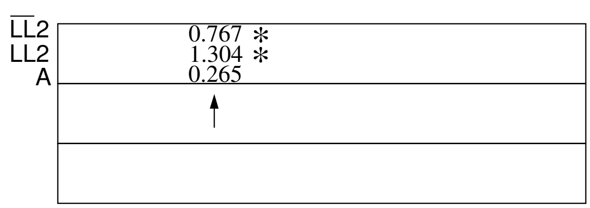
Hyperbolic functions can be calculated from the following formulas.

$$\begin{aligned}
\sinh x &= \frac{e^x - x^{-x}}{2} \\
\cosh x &= \frac{e^x + x^{-x}}{2} \\
\tanh x &= \frac{e^x - x^{-x}}{e^x + x^{-x}}
\end{aligned}$$

Since this slide rule is so designed that when x is set over the A scale, e^x can be found on the LL scale and e^{-x} can be found on the the $\overline{\text{LL}}$ scale at the same time, this slide rule can be conveniently used for this type of calculation.

Ex. 8.5

$$\begin{aligned}
\sinh 0.265 &= 0.2685 \\
\cosh 0.265 &= 1.036 \\
\tanh 0.265 &= 0.259
\end{aligned}$$



$$e^x - e^{-x} = 1.304 - 0.767 = 0.537$$

$$e^x + e^{-x} = 1.304 + 0.767 = 2.071$$

$$\sinh 0.265 = \frac{0.537}{2} = 0.2685$$

$$\sinh 0.265 = \frac{2.071}{2} = 1.036$$

$$\sinh 0.265 = \frac{0.537}{2.071} = 0.259$$

Chapter 9

Electronic Calculations

The scales on the back face of this rule are specially designed and arranged that various electronics calculations are very quickly performed.

1. The black coded group (C, C_Z, L, Z and f_0) is used for resonant frequency $f_0 = \dfrac{1}{2\pi\sqrt{LC}}$ and surge impedance $Z = \sqrt{\dfrac{L}{C}}$ calculations.

2. The green coded group (X_L, X_C, F, L, C, P and Q) is used for impedance $Z = \sqrt{x^2 + y^2}$, capacitance reactance $X_C = \dfrac{1}{2\pi FC}$ and inductive reactance $X_L = 2\pi FL$ calculations.

3. the red coded group (T_L, T_C, R, L, C, f_m, r_1, and r_2) is used to find time constants $T_C = RC$, $T_L = L/R$ and critical frequency (-3 dB frequency point) $f_m = \dfrac{1}{2\pi RC}$. r_1 and r_2 are used for parallel resistance and series capacitance calculations.

Some of the scales which belong to the red color group, however, such as T_L, r_1, etc., are also used as the green color group scales of X_L, X_C, etc. In other words, one same scale is commonly used for both T_L (red) and X_L (green) scales. For example, the T_L scale is, if read by the units of mμs, μs, ms, and s (red), used for calculating $T_L = \frac{L}{R}$. The same scale is, if read by the units of 1 mΩ, 1 Ω, 1 kΩ, and 1 MΩ, used to calculate $X_L = 2\pi FL$.

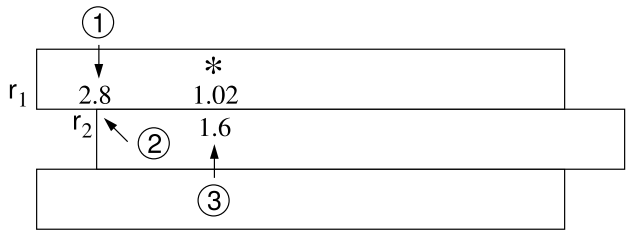
Some of these scales consist of 12 cycled logarithmic scales, and can be directly read on the scale already with the decimal point. Since these values are read with the decimal point, the numerals and marks to express the unit have been much simplified. For example, the L scale (black) is only marked with the unit of 0.001μH, 1μH, 1 mH, H, and 100 H.

Intermediate units are only shown by ($\cdot\cdot$) or ($\cdot$). ($\cdot\cdot$) is marked at the positions 10^2 and ($\cdot$) at 10.

9.1 Parallel Resistance and Series Capacitance

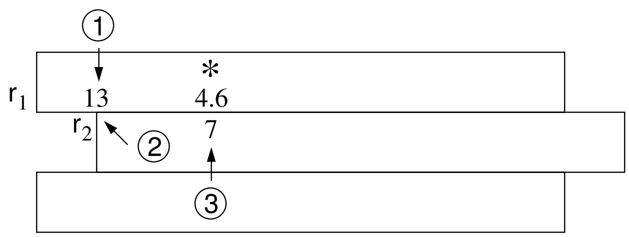
The r_1 and r_2 scales on the back face are non-logarithmic and are used to calculate parallel resistance.

Ex. 9.1 Find the total resistance when $r_1 = 2.8$ kΩ and $r_2 = 1.6$ kΩ are connected in parallel.

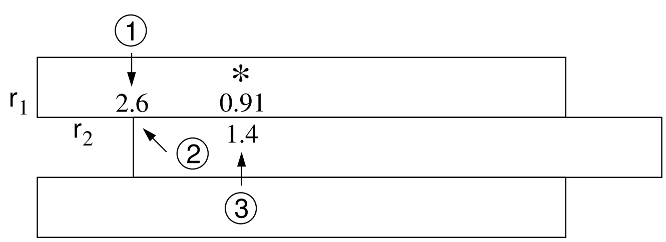


Answer 1.02 kΩ

Ex. 9.2 Fine the total resistance when $r_1 = 1.3$ kΩ and $r_2 = 0.7$ kΩ are connected in parallel.

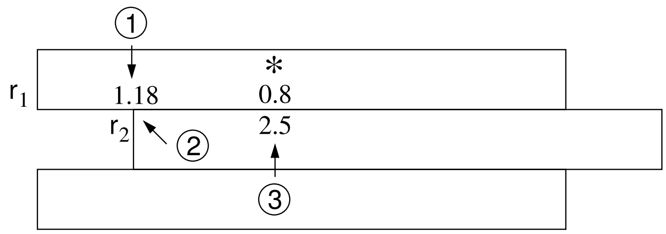


(Note) When $r_1 = 1.3$ kΩ and $r_2 = 0.7$ kΩ are directly set on the r_1 and r_2 scales, the answer cannot be found within the rule. As illustrated above, multiply r_1 and r_2 by 10 and then divide the obtained answer by 10. This calculation, however, is not very precise. Precision can be improved by the operation shown below. 2.6 and 1.4 are obtained by doubling 1.3 and 0.7. Set these numbers on the r_1 and r_2 scale. The answer 0.455, then, can be found by dividing the 0.910 by 2.



Answer 0.455 Ω

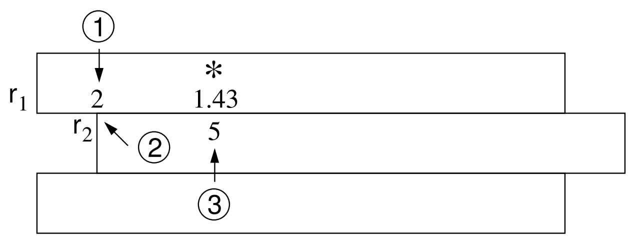
Ex. 9.3 In a resistive circuit, total resistance = 800 kΩ and r_1 = 2.5 kΩ. Find r_2.



Answer 1.18 kΩ

Ex. 9.4 Find the total capacitance C when 0.05 μF and 0.02 μF are connected in series.

$$\begin{aligned}\frac{1}{C} &= \frac{1}{0.05\ \mu\text{F}} + \frac{1}{0.02\ \mu\text{F}} \\ &= \left(\frac{1}{5} + \frac{1}{2}\right) \times \frac{1}{0.01\ \mu\text{F}} \\ &= 0.0143\ \mu\text{F}\end{aligned}$$



Answer 0.0143 μF

9.2 Impedance

The P and Q scales have non-logarithmic graduations and are used for calculation of the formula:

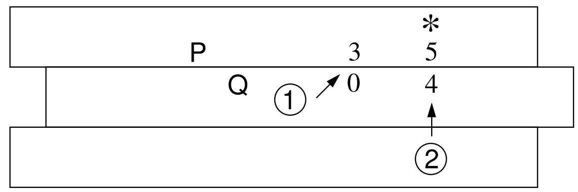
$$Z = \sqrt{R^2 + X^2} \quad (\text{Conditional on } X = \omega L - \frac{1}{\omega C})$$

The above formula can also be performed by using the S and T scales. However, when finding the phase angle is not necessary, it is much simpler to use the P and Q scales.

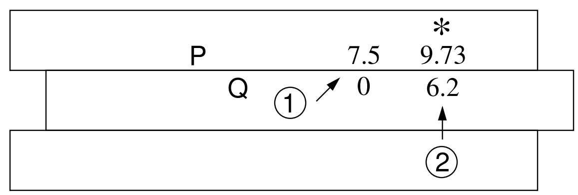
The P and Q scales are marked with numbers from 0 to 14; however, they can also be read as 0 ∼ 1.4, 0 ∼ 140. When performing a calculation, one scale cannot be as 0 ∼ 14 at the same time the other scale is read as 0 ∼ 1.4. Both scales should be in the same units.

Ex. 9.5 The absolute value of Z, the total impedance when $R = 3\ \Omega$ is connected in series with $X = 4\ \Omega$, becomes $\sqrt{3^3 + 4^3} = 5 \quad \therefore Z = 5$.

The above formula can be calculated in the manner shown below by use of the P and Q scales.



Ex. 9.6 $\sqrt{75^2 + 62^2} = 97.3$

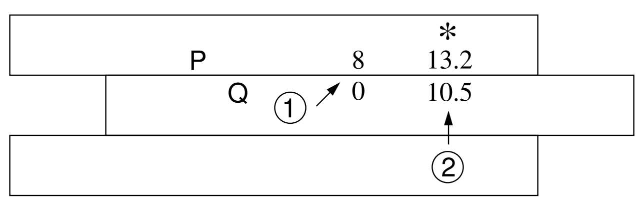


Divide both 75 and 62 by 10 to obtain 7.5 and 6.2, then multiply the given number 9.73 by 10 as illustrated in the above manner, and finally find the answer 97.3.

Ex. 9.7 $\sqrt{16^2 + 21^2} = 26.4$

The above calculation can be performed reading the P and Q scales at the range from $0 \sim 140$; however, precision is improved if the above numbers are divided by two to 8 and 10.5, and performing the calculation $\sqrt{8^2 + 10.5^2}$.

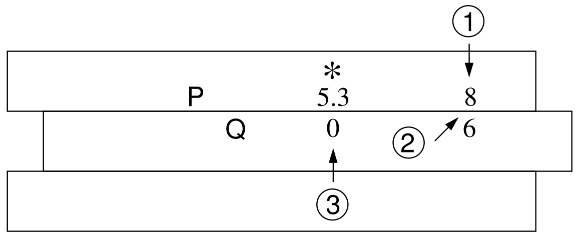
The answer 13.2 found on the P scale will be then multiplied by two ot obtain 26.4.



$13.2 \times 2 = 26.4$ Answer 26.4

Ex. 9.8 The total impedance Z is to be 0.8 ohms when resistance $R = 0.6\ \Omega$ is connected in series with reactance X. What value should X be?

$$X = \sqrt{Z^2 - R^2} = \sqrt{0.8^2 - 0.6^2} = 0.53\ \Omega$$



Answer 0.53 Ω

9.3 Reactance

There are reactance formulas:

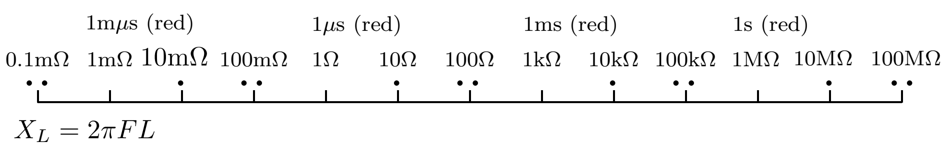
Inductive reactance $X_L = 2\pi FL\ (\Omega)$

Capacitive reactance $X_C = \dfrac{1}{2\pi FC}\ (\Omega)$

Reactance calculations can be performed by groups L, C of the slide (each colored green) and X_L, X_C, and F on the upper part of the body on the back face.

These scales are all 12 unit logarithmic scales. Units are marked every three units and the rest are indicated by " · " and " ·· ".

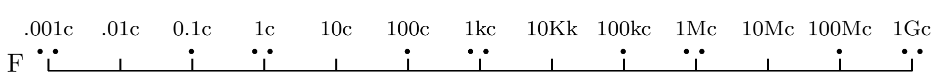
Inductive reactance between 0.1 mΩ to 100 MΩ can be read by reading the black numbers on the X_L scale.



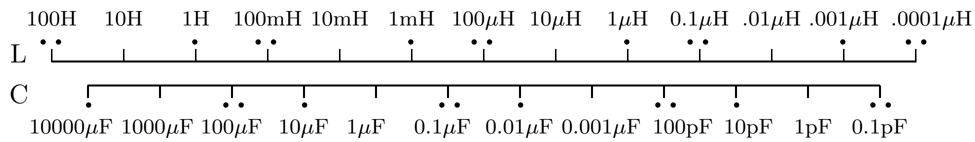
This scale can be read from 0.1 mμs to 100 s ("s" stands for "seconds") with the red numbers. However, when finding reactance (units are Ω) the black numbers should be read.

Since the X_C scale has reciprocal graduations, 0.1 mΩ to 100 MΩ can be read according to the black numbers; of course, this scale also has red numbers, but when it is read as the X_C scale it should be according to the black numbers.

The F scale only has black numbers ranging from 0.001 c/s (Hz) to 1 Gc/s (GHz). Frequency F can be read with this scale.



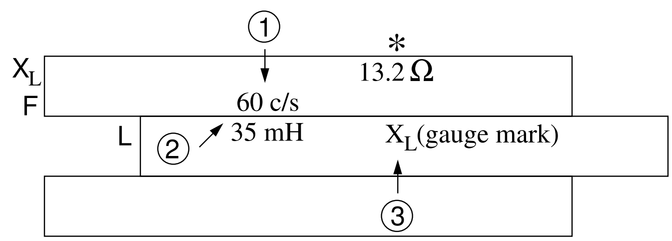
The L scale is numbered from right to left and ranges from 0.001 μH $\sim$ 100 H from the right to left. The C scale is the same and ranges from 0.1 pF $\sim$ 10000μF (0.01 mF) from the right to left.



The 10 mH graduation on the L scale (green) is marked with the gauge mark X_L (green), and the 1 μF graduation on the C scale (green) is marked with the gauge mark X_C (green).

When X_L and X_C are to be found, with F, L and C given, the values are on the X_L scale opposite the gauge mark X_L and on the X_C scale opposite the X_C gauge mark. In other words, the gauge mark and the scale to correspond to it are shown by the same designation such as X_L, X_C (green), T_L, T_C (red), etc.

Ex. 9.9 If inductance L = 35 mH, frequency F = 60 c/s (Hz) are given, find reactance $X_L (= 2\pi F L)$.

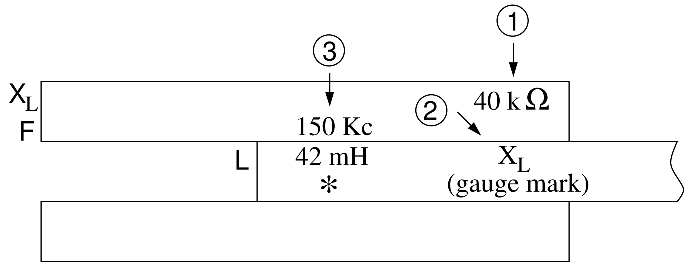


Operation:

1. Set the hairline over 60 c/s on the F scale,
2. Move 35 mH on the L scale under the hairline,
3. Set the hairline over the gauge mark X_L on the L scale, and read 13.2 Ω on the X_L scale under the hairline.

Answer 13.2 Ω

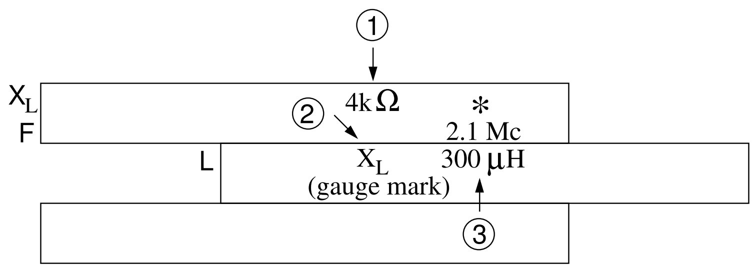
Ex. 9.10 What is the impedance when the reactance is 40 Ω at a frequency of 150 kc (kHz)?



If reactance is given, as illustrated above, set the gauge mark X_L over the reactance, and find the value on the L scale which corresponds to the F scale.

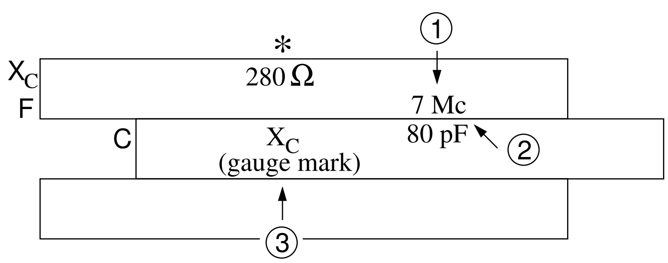
Answer 42 mH

Ex. 9.11 Find the frequency at which a peaking coil of L= 300 μH has a reactance of $X_L = 40$ kΩ.



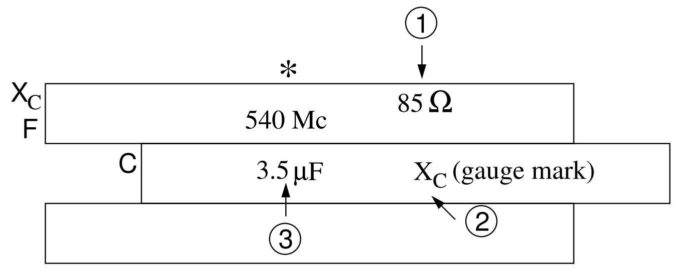
Answer 2.1 Mc (MHz)

Ex. 9.12 Find the capacitive reactance $X_C = \dfrac{1}{2\pi FC}$ of a C = 80 pF electrolytic capacitor at a frequency of F = 7 Mc (MHz).



Answer 280 Ω

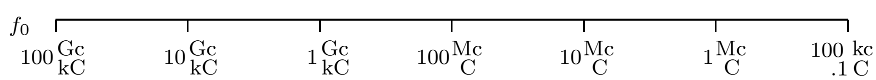
Ex. 9.13 Given: Capacitive reactance of 85 Ω and capacitance of 3.5 μF. Find the frequency.



Answer 540 c (Hz)

9.4 Resonant Frequency

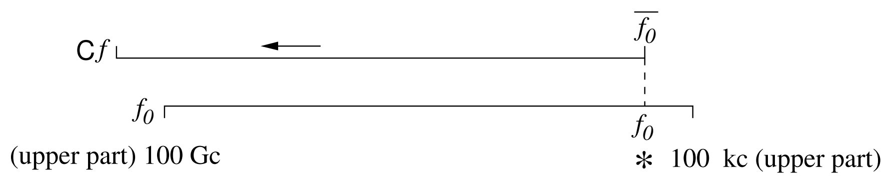
Resonant frequency $f_0 = \dfrac{1}{2\pi\sqrt{LC}}$ can be calculated by using the Cf (it indicates capacitance C) of the slide and the L and f_0 scales on the body within the groups which are graduated with the black numbers on the left end of the rule. It will be noted that the slide has another C_Z scale, but this should not be confused with the other one since it is used for calculation ofr surge impedance $Z = \sqrt{\dfrac{L}{C}}$ which will be explained in a later chapter.
Capacitance for finding f_0 is read on the Cf scale.
Capacitance for finding Z is read on the C_Z scale.
The two gauge marks $\underline{f_0}$ and $\overline{f_0}$ are at both the left and right ends of the Cf scale.
Therefore, the f_0 scale which corresponds to these gauge marks becomes the resonant frequency. The f_0 scale is a six unit logarithmic scale (inversely graduated) with its units marked in two lines.
When the units on the upper are read: 100 Gc (GHz) $\rightarrow$ 100 Kc (kHz)
When the units on the lower part are read: 100 Kc (kHz) $\rightarrow$ 0.1 c (Hz)



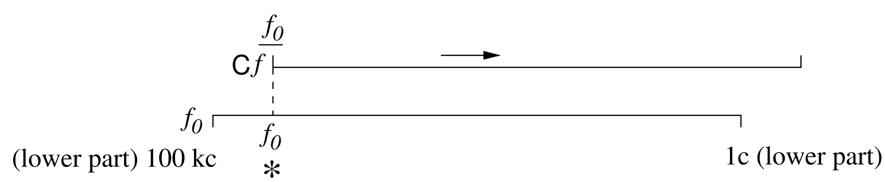
The units on the upper and lower parts and the gauge marks $\overline{f_0}$ (the line is over the f_0) and $\underline{f_0}$ (the line is under the f_0) on the Cf scale have the following relationship. When the L and Cf scales are set, the slide protrudes toward either the left or right. Resonant frequency $f_0 = \dfrac{1}{2\pi\sqrt{LC}}$ is found on the f_0 scale opposite either index $\overline{f_0}$ or $\underline{f_0}$ on the CF scale.

When the gauge mark $\overline{f_0}$ is used, the f_0 scale is read with the units on the upper part. When the gauge mark $\underline{f_0}$ is used, the f_0 scale is read with the units on the lower part.

1. (The gauge mark $\overline{f_0}$ corresponds to the upper part)



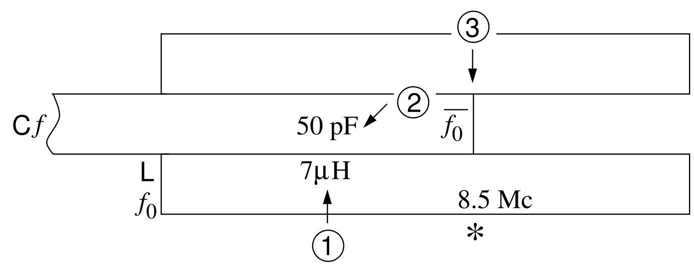
2. (The gauge mark $\underline{f_0}$ corresponds to the lower part)



The numbers 3 mm to 3,000 m are marked in red under the f_0 scale. These indicate wavelength (λ) corresponding to frequency when the f_0 scale is read with the units on the upper part. The following relationship exists.

$$\lambda f = 3 \times 10^8, \quad \text{between frequency } f \text{ and wavelength } \lambda$$

Ex. 9.14 Find the resonant frequency $f_0 = \dfrac{1}{2\pi\sqrt{LC}}$ of an LC circuit composed of self-inductance L= 7 μH and capacitance C= 50 pF.

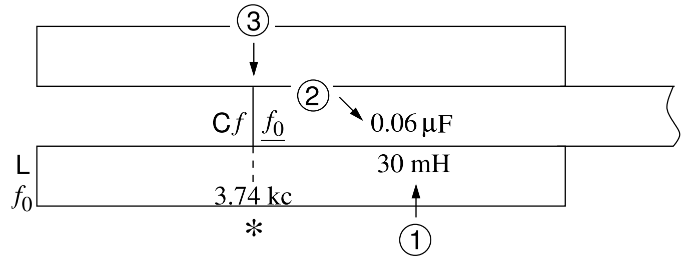


Answer 8.5 Mc (MHz)

(Operation)

1. Set 50 pF on the Cf scale over 7 μH on the L scale.
2. Read the value 8.5 Mc (the f_0 scale is read with the units marked on the upper part) on the f_0 scale corresponding to the gauge mark f_0.

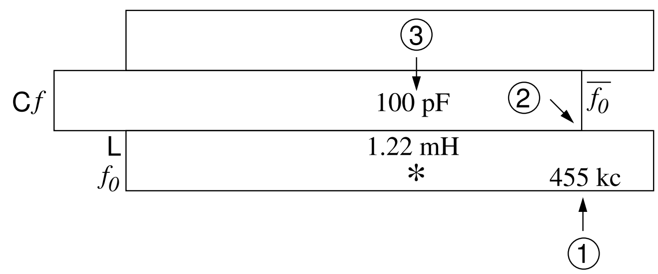
Ex. 9.15 find resonant frequency f_0 when L= 30 mH and C= 0.06 μF.



Answer 3.74 Kc (kHz)

In this operation, since the slide protrudes to the right and the mark f_0, the f_0 scale can be read with the units on the lower part.

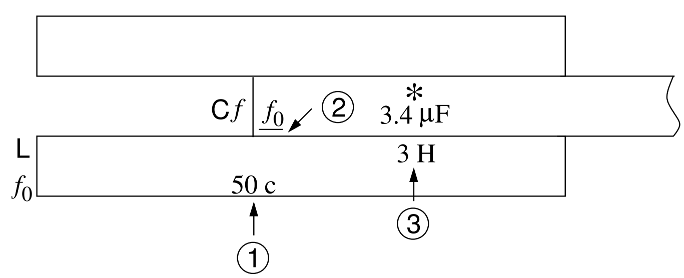
Ex. 9.16 How much inductance L should there be in order to obtain resonance at the intermediate frequency f_0 = 455 kc of an AM receiver when C= 100 pF.



Answer 1.22 mH

To find L with a given f_0 and C, first set the gauge mark f_0 over the graduation on the f_0 scale. The gauge mark $\overline{f_0}$ is set when the graduation on the f_0 scale is read with the units on the upper part, and the gauge mark $\underline{f_0}$ is set when the graduation on the f_0 scale is read with the units on the lower part.

Ex. 9.17 Find the value of C required to resonate at f_0 = 50 c/s when L= 3 H.



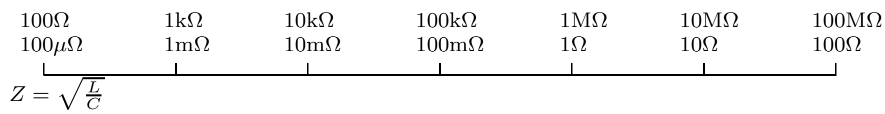
Answer 3.4 μF

9.5 Surge Impedance

Surge impedance $Z = \sqrt{\dfrac{L}{C}}$ can be calculated with the C_Z, L and Z marked in black on the left end of the slide rule.

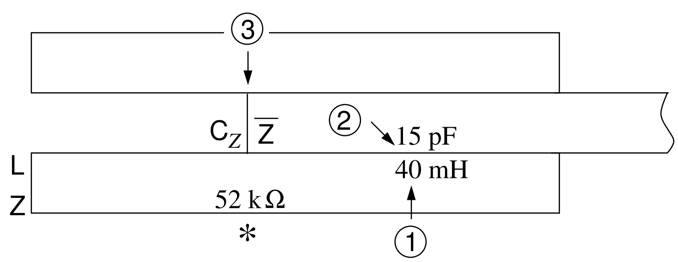
Set L on the L scale and C on the C_Z scale, and find Z from the gauge mark Z or $\underline{Z}$ at the right and left ends of the C_Z scales.

The Z scale is the same as resonant frequency in that the units are marked on the upper and lower sides. If they are read on the upper side, they are 100 Ω ∼ 100 MΩ from the left. If they are read on the lower side, they are 100 μΩ ∼ 100 Ω.



When the gauge mark $\overline{Z}$ (the left end) is used, the units on the upper side are read, and when the gauge mark $\underline{Z}$ (the right end) is used, the units on the lower side are read, that is, it is exactly the same as in the case of resonant frequency. At the beginning of calculation, the value of the Z scale is sometimes set to either gauge mark $\underline{Z}$ or $\overline{Z}$. Set to $\overline{Z}$ when the Z scale is read with the units on the upper side and set to $\underline{Z}$ when the Z scale is read with the units on the lower side.

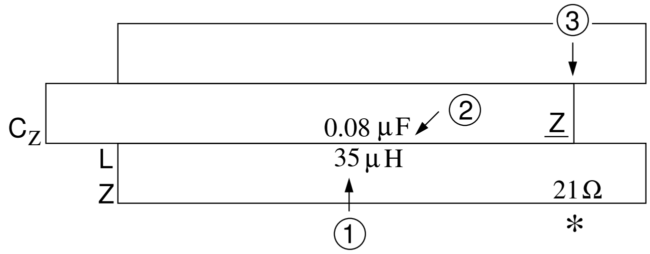
Ex. 9.18 Find the surge impedance $Z = \sqrt{\dfrac{L}{C}}$ when L= 40 mH and C= 15 pF.



When the graduations on the L scale and C_Z scale are set, the slide protrudes to the right and the gauge mark $\overline{Z}$ must be used; therefore, in this case the Z scale must also be read with the units on the upper side.

Answer 52 kΩ

Ex. 9.19 Find the surge impedance when L= 35 μH and C= 0.08 μC.

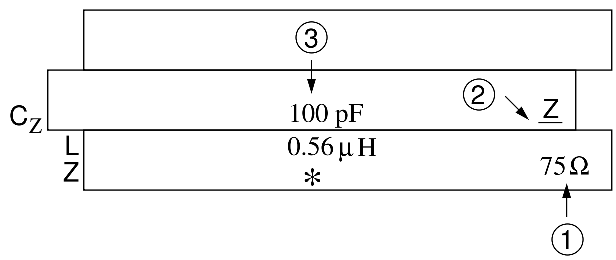


Since the slide protrudes to the left and the gauge mark $\underline{Z}$ is used, the Z scale, in this problem, must be read with the units on the lower side.

Answer 21 Ω

Ex. 9.20 Find the inductance L of a length of Z= 75 Ω coaxial cable that is cut so that the capacitance between the conductor and sheath is C= 100 pF.

This problem is to find L, if Z and C are given, at $Z = \sqrt{\dfrac{L}{C}}$



Answer 0.56 μF

9.6 Time Constant

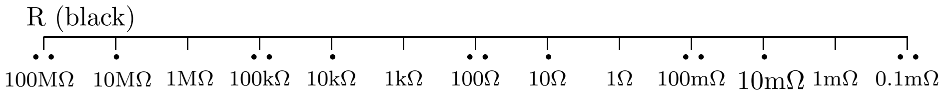
The time constant of one RC circuit and RL circuit can be shown by the following formulas.

RC circuit $T_C = CR$

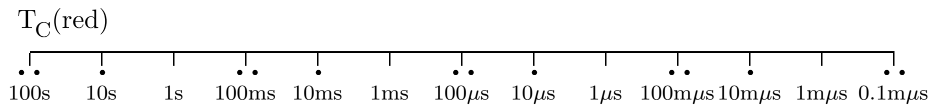
RL circuit $T_L = \dfrac{L}{R}$

The scales marked T_L, R, T_C, L and C in red on the right end of the slide rule can be used for calculation. The scale which is on the second line from the top is marked R and T_C and used in combination with the R and T_C scales.

When it is read as R, it must be read with the units in black in the same manner as reactance X_C. Its range is from right 0.1 mΩ $\sim$ 100 MΩ (reciprocal graduation).

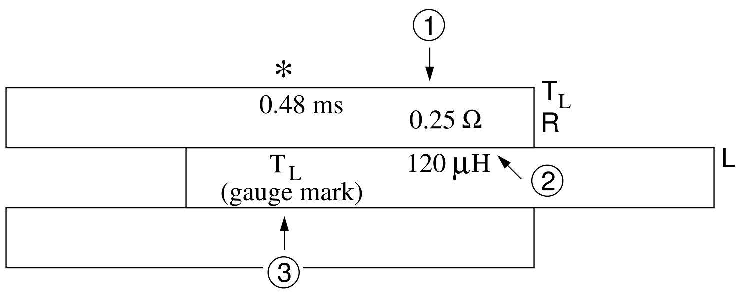


When it is read as T_C, it must be read according to the red numbers. Its range is then from right 0.1 mμs $\sim$ 100 s.



The gauge mark T_L (red) is marked at 10 mH on the L scale, and the gauge mark T_C (red) is marked at 1 μF on the C scale. The time constant corresponds to the gauge marks T_L and on the T_L scale and T_C on the T_C scale.

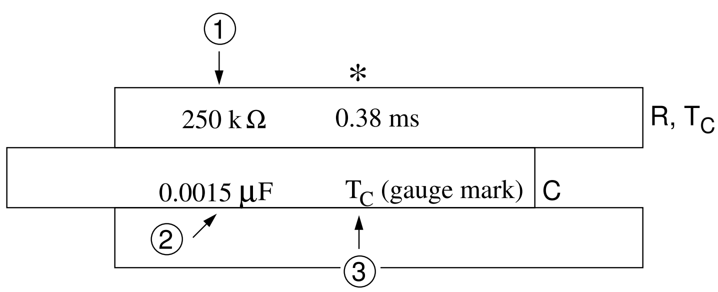
Ex. 9.21 Fin the time constant $T_L = \dfrac{L}{R}$ of a coil which has a resistance R= 0.25 Ω and inductance L= 120 μH.



(Operation) Set 0.25 Ω on the R scale (in this case, the R and T_C scales) and move it to 120 μH on the L scale. Then find the value 0.48 ms as the answer on the T_L scale which corresponds to the gauge mark T_L.

Answer 0.48 ms

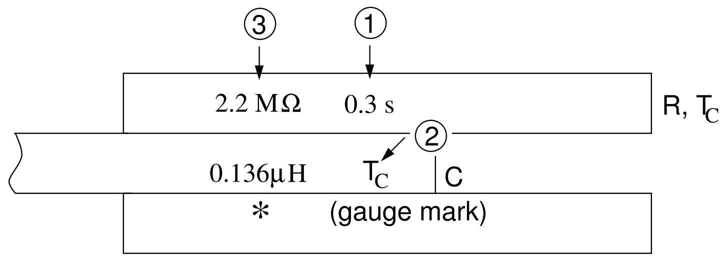
Ex. 9.22 Find the time constant $T_C = CR$ of an RC circuit where $R =$ 250 kΩ and $C = 0.0015\ \mu$F.



(Operation) Set 250 kΩ (black) on the R scale (the R and T_C scales) and move it to 0.0015 μF on the C scale, and read the value 0.38 ms (380 μs) on the R and T_C scale with the red units on the T_C scale which correspond to the gauge mark T_C.

Answer 0.38 ms

Ex. 9.23 Find C of an RC circuit when $R = 2.2$ MΩ and time constant $T_C = 0.35$ s are given.



(Operation) When constant T_C is given, first set the gauge mark T_C over 0.3 s (300 ms) on the T_C scale, and find 0.136 μF which corresponds to 2.2 MΩ (black) on the R scale.

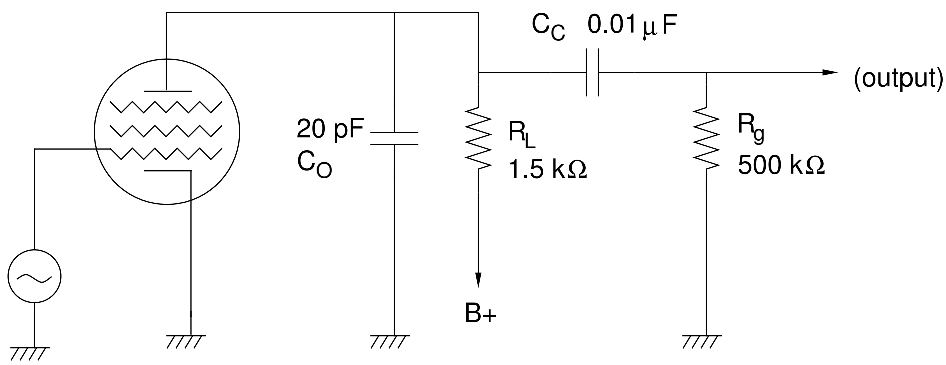
Since the R and T_C scale is divided into two units which can be read, special care is required.

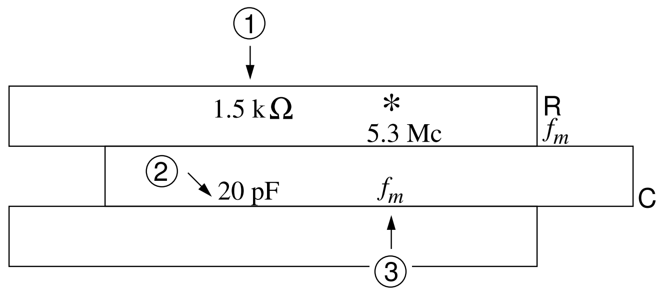
Answer 0.136 μF

9.7 Critical Frequency (–3 dB Frequency Point)

In an amplifier circuit, the frequency at which the gain becomes –3 dB is called the high-pass critical frequency and is given as $f_m = \frac{1}{2\pi RC}$. This can also be the low-pass critical frequency. How to find $T_C = RC$ if R and C are known is given in the previous chapter. The f_m scale located under the T_C scale corresponds to R and C on the T_C scale to give the relationship $\frac{1}{2\pi RC}$. Therefore, $f_m = \frac{1}{2\pi RC}$ on the f_m scale can be obtained in the same manner as finding $T_C = RC$.

Ex. 9.24 Find the high-pass frequency ($f_m = \dfrac{1}{2\pi RC}$) when the load resistance $R_L = 1.5$ kΩ and stray capacitance $C_0 = 20$ pF as shown in the below illustration are given; but, the internal resistance of the vacuum tube is assumed to be much larger than the load resistance.

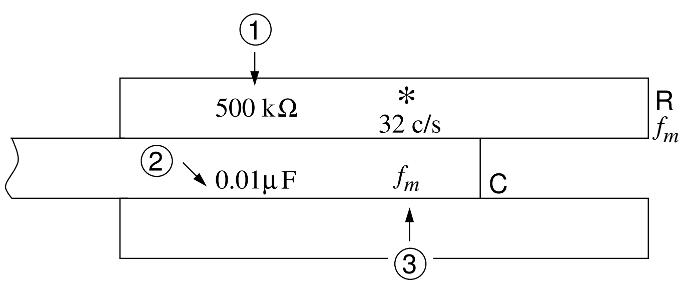




(Operation) Set 20 pF on the C scale over 1.5 kΩ (black) on the R scale and find the high-pass cut off frequency which is 5.3 Mc (MHz) on f_m corresponding with the gauge mark f_m.

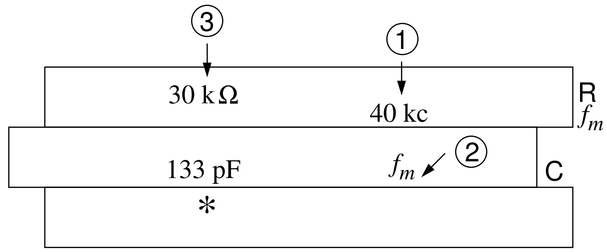
Answer 5.3 Mc (MHz)

Ex. 9.25 Find th elow-pass cut off frequency of C_c and R_g of the previous diagram when $R_g = 500$ kΩ and $C_c = 0.01$ μF.



Answer 32 s/c (Hz)

Ex. 9.26 Find the stray capacitance of a resistance coupled amplifier when the high-pass cut off frequency ($f_m = \frac{1}{2\pi RC}$) is 40 kc and load resistance $R = 30\ \mathrm{k}\Omega$.



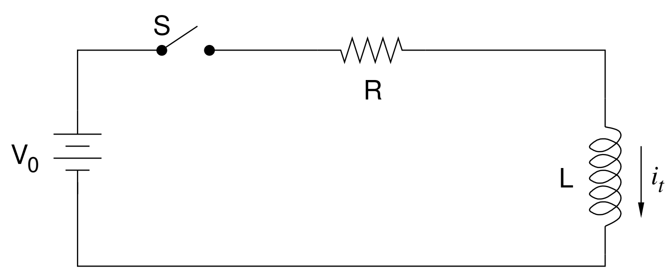
Answer 133 μF

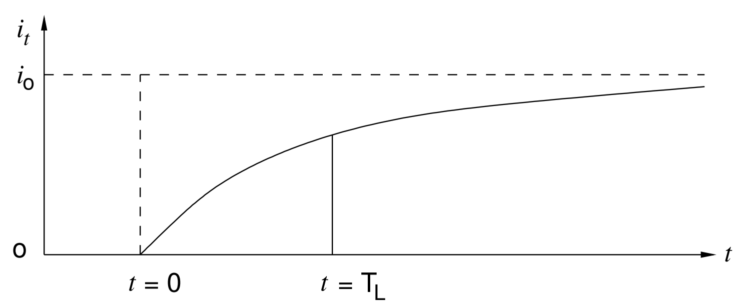
9.8 Application

Ex. 9.27 Find i_t at $t = 63.5\ \mu$s (horizontal period of TV) of the current curve after the switch in a circuit which shows the relationship

$$i_t = i_0(1 - e^{-\frac{t}{T_L}}), \quad i_0 = \frac{V_0}{R}, \quad T_L = \frac{L}{R}$$

is turned on where $L = 3.3$ mH, $R = 1.5\ \Omega$ and $V_0 = 12.5$ V.





(Solution)

1. Find $T_L = \dfrac{L}{R} = 2.2$ ms, from $R = 1.5\ \Omega$ and $L = 3.3$ mH.

2. Find $i_0 = \dfrac{V_0}{R} = 8.3$ A, from $R = 1.5\ \Omega$ and $V_0 = 12.5$ V.

3. Find $e^{-\frac{t}{T_L}} = 0.9715$, from $T_L = 2.2$ ms, $t = 63.5\ \mu$s.

4. $i_0 = 8.3$ A, $e^{-\frac{t}{T_L}} = 0.9715$

$$\begin{aligned} i_t = i_0(1 - e^{-\frac{t}{T_L}}) &= 8.3 \text{ A} \times (1 - 0.9715) \\ &= 8.3 \text{ A} \times 0.0285 \\ &= 0.326 \text{ A} \end{aligned}$$

* How to find $e^{-\frac{t}{T_L}}$
The value of $\dfrac{63.5\,\mu\text{s}}{2.2\,\text{ms}}$ is considered to be between $0.01 \sim 0.1$ based on rough estimation, and the answer is found on the $\overline{\text{LL}}1$ scale.

Ex. 9.28 Find the time t required to reach $\frac{1}{5}$ of i_t or i_0 in the circuit of the previous example.

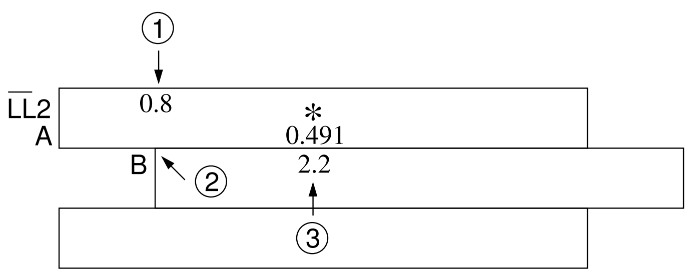
(Solution)

This problem is to find t which is $1 - e^{-\frac{t}{\pi}} = 0.2$ in the formula $i_t = i_0(1 - e^{-\frac{t}{T_L}})$.

$T_L = \dfrac{L}{R} = 2.2$ ms has already been found, and should therefore be used.

First set the left index on the B scale over 0.8 on the $\overline{\text{LL}}2$ scale, and then find the value on the A scale which corresponds to $T_L = 2.2$ ms on the B scale; but, 0.1 should be smaller than $\dfrac{t}{T_L}$ so that $e^{-\frac{t}{T_L}} - 0.8$.

Therefore, the value on the A scale is read $t = 0.491$ ms.



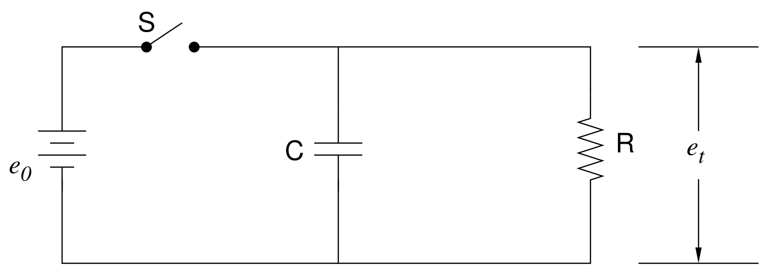
Answer 0.491 ms

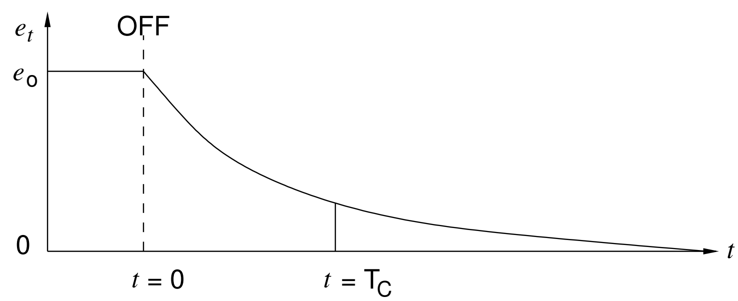
Ex. 9.29 In a circuit which can be given in the form:

$$e_t = e_0 \cdot e^{-\frac{t}{T_C}}, \quad T_C = CR$$

1. Find time constant T_C
2. At characteristic voltage at time t after the switch is turned on, find the value e_t
   (a) at $t = \frac{1}{10} \times T_C$
   (b) at $t = 5 \times T_C$

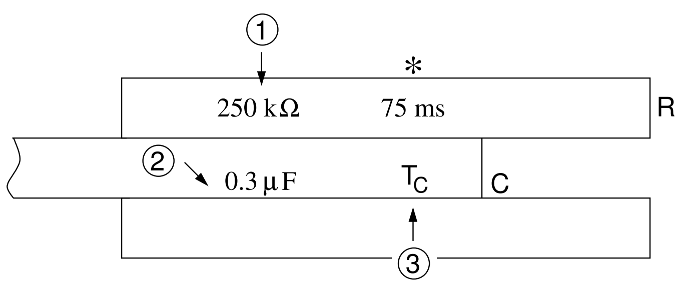
$R = 250$ kΩ, $C = 0.3\,\mu$F and $e_0 = 6.3$ V.





(Solution)

1. From $R = 250$ kΩ and $C = 0.3\mu$F, find time constant $T_C = CR = 0.75$ ms.



2. $e^{-0.1} = 0.905, \quad e^{-5} = 0.0067$ (The A, $\overline{\text{LL}}1$ and $\overline{\text{LL}}2$ scales are used.)

   (a) $6.3\,\text{V} \times 0.905 = 5.7\,\text{V}$

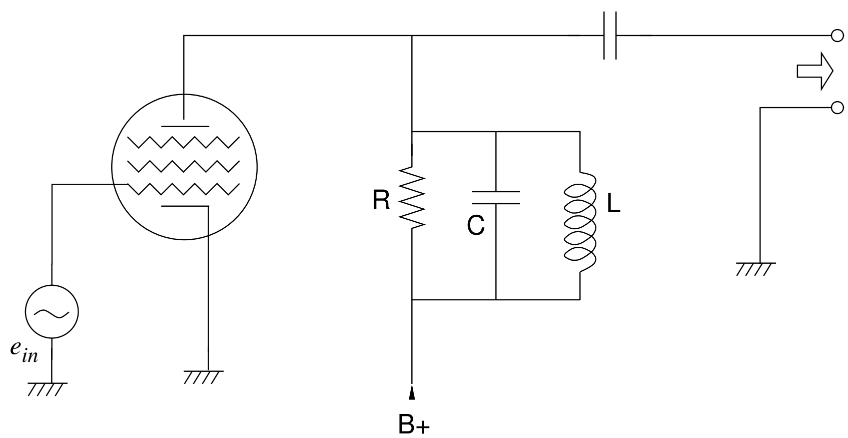
   (b) $6.3\,\text{V} \times 0.0067 = 0.0422\,\text{V}$

Ex. 9.30 Tuned amplifier circuit (See illustration below)

1. Find inductance L required to obtain resonance with $C = 50$ pF at a frequency of $f_0 = 3.58$ Mc (MHz).

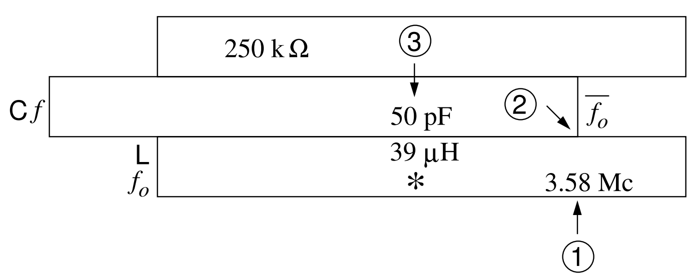
2. Find the value of damping resistance R which must be inserted in parallel to make the tuned circuit have a $Q = 7$.

3. Calculate the voltage gain at the center frequency between the grid and plate of an amplifier tube having a mutual conductance of $g_m = 4800\,\mu\mho$.



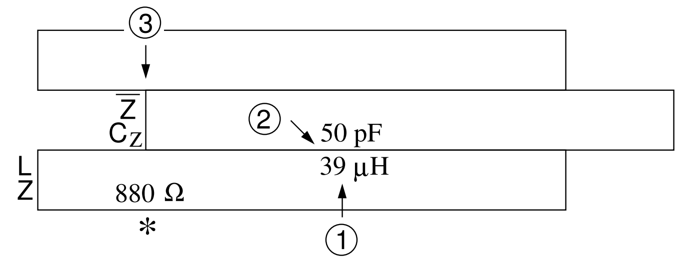
(Solution)

1. Find L of $f_0 = \dfrac{1}{2\pi\sqrt{LC}}$ if $C = 50$ pF and $f_0 = 3.58$ Mc are given.



Answer $L = 39\,\mu$H

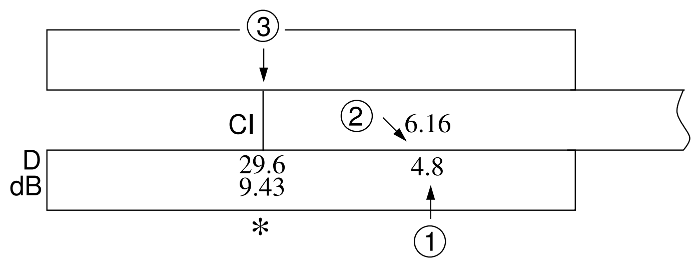
2. First find $Z = \sqrt{\dfrac{L}{C}}$ from $L = 39\mu\text{H}$ and $C = 50\,\text{pF}$, setting $Q = \dfrac{R}{\sqrt{\dfrac{L}{C}}} = 7$.



Then, read $R = 880\,\Omega \times 7 = 6.16\text{ k}\Omega$ from $Q = \dfrac{R}{880\,\Omega} = 7$.

Answer $R = 6.16\text{ k}\Omega$

3. Find G from $g_m = 4800\,\mu\mho$, $R = 6.16\text{ k}\Omega$ at voltage gain $G = 20\log(g_m \times R)$.



(NOTE) If $4800\,\mu\Omega \times 6.16\text{ k}\Omega = 4.8 \times 10^{-3} \times 6.16 \times 10^{3} = 4.8 \times 6.16 = 30$ is roughly calculated, it will be understood that dB is between $20 \sim 40$; therefore, add 20 to the given 9.43 and read 29.43.

Answer 29.43 dB

Care and Adjustment of the Slide Rule

When the Slide Does Not Move Easily

Pull the slide out of the body and remove any dirt adhered to the sliding surfaces of the slide and the body with a toothbrush. Using a little wax will also help.

Every Hemmi slide rule should come to you in proper adjusted condition. However, the interaction of the slide and body, if necessary, can be adjusted to your own preference.

First, loosen a screw at one end of the rule. Them, if you feel the slide fits tightly, pull this end away from the slide, and if you feel the slide fits loosely, push this end toward the slide and retighten the screw. Do the same at the other end repeat the same operation until the slide fits properly.

When the Indicator Glass Becomes Dirty

Place a narrow piece of paper between the indicator glass and the surface of the rule, press the indicator glass against the piece of paper, and work the indicator back and forth several times until the dirt particles under the glass adhere to the piece of paper.

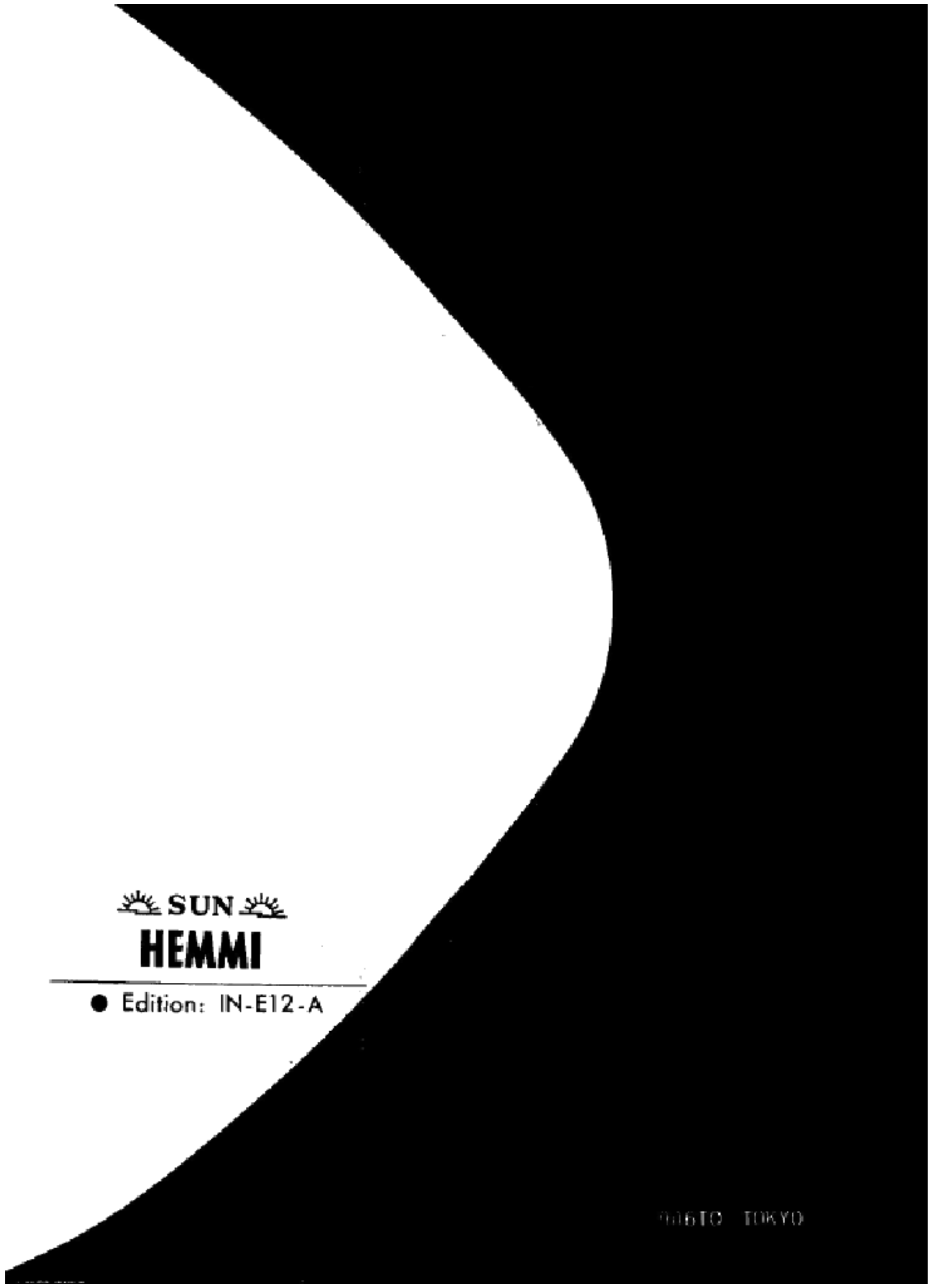
How to Adjust the Hairline

The hairline should always be perpendicular to the scales. If it is not, loosen the four screws of the indicator frame and move the glass until perfect alignment is obtained and tighten the screws.

How to Adjust the Scales

When the slide is moved until the D and C scales coincide, the DF and CF or A and B scales should coincide. However, the adjustment of the rule may be lost if the rule is dropped or severely jarred. In this case, loosen the screws at both ends of the rule and move the upper body member right or left until the DF or A scale coincides with the CF or B scale, and tighten the screws.


No. 266 Slide Rule
Front Face
Back Face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