SUN HEMMI

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HEMMI

SUN HEMMI

INSTRUCTION MANUAL FOR HEMMI 257L SLIDE RULE

HEMMI SLIDE RULE CO., LTD.
TOKYO, JAPAN

NO. 257L SLIDE RULE

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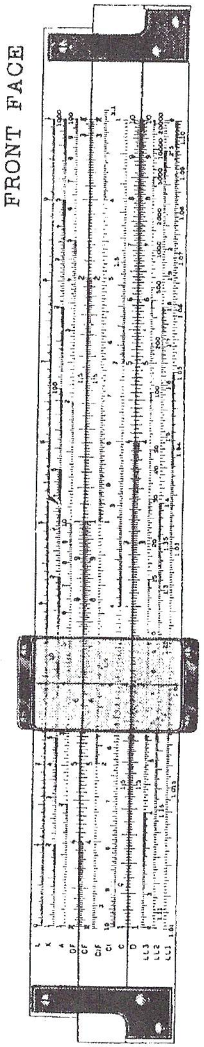

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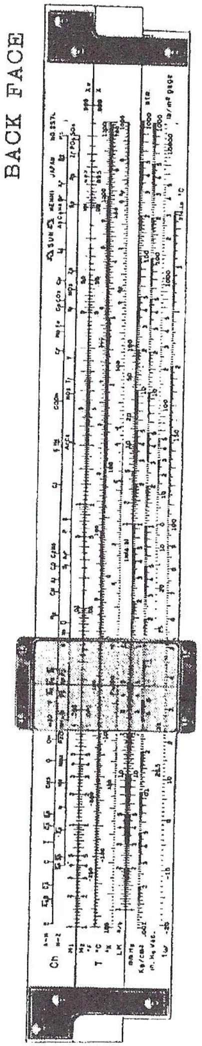


INSTRUCTION MANUAL FOR HEMMI NO. 257L (25cm DUPLEX·TYPE) SLIDE RULE

The Hemmi No. 257L slide rule is especially designed for use by chemical engineers. The scales for ordinary multiplication and division, as well as those for square, square root, logarithms, and exponents, are arranged on the front of the rule while the special chemical engineering scales are systematically arranged on the back.

(1) The rule is also equipped with gauge marks which permit the determination of atomic and molecular weights of the major atomic groups and elements.

(2) °F, °C, and °K scales are also provided for temperature conversion. Mutual conversion is possible by merely moving the indicator. In addition, °R can also be found by using the D scale in conjunction with the above scales.

(3) Pressure units, in kg/cm^2, mmHg, in. Hg Vac, atm, and psi Gage conversion are also possible.

(4) Seales which permit mutual conversion between molar fraction, weight fraction, and volume fraction are also provided.

(5) Scales which show the temperature of water, vapor (steam) and saturated vapor pressure, as well as adiabatic compression and adiabatic expansion of gases are provided and arranged to improve calculation efficiency.

CHAPTER 1. READING THE SCALES.

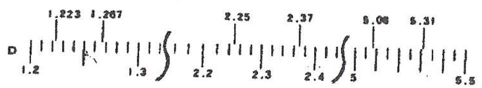
In order to master the slide rule, you must first practice reading the scales quickly and accurately. This chapter explains how to read the D scale which is the fundamental scale of the No.259D slide rule and is one used most often.

(1) SCALE DIVISIONS

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

Between 1-2 One division is 0.01
Between 2-4 One division is 0.02
Between 4-10 One division is 0.05

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



(2) SIGNIFICANT FIGURES

The D scale is read without regard to decimal point location. For example, 0.237, 2.37, and 237 are read 237 (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 237 (two three seven). In 237 (two three seven), the 2 (two) is called the first "significant figure.".

(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 procedure will be explained in diagram form in this instruction manual. The symbols used in the diagrams are:

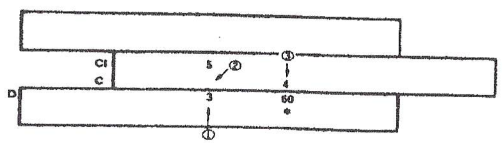
Slide Operation ⁄⁄ ⁄ ⧵⧵ Moving the slide to the position of the arrow with respect to the body of the rule.

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 $3\times5\times4=60$ 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.

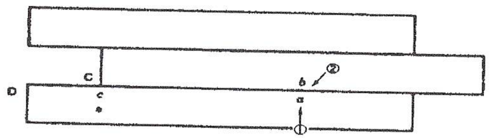
CHAPTER 2. MULTIPLICATION AND DIVISION. (1)

§ 1. DIVISION

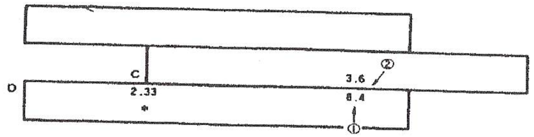
FUNDAMENTAL OPERATION (1) $a \div b = c$

(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.

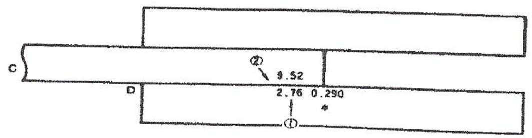


Ex. 2.1 8.4÷3.6=2.33



Ex. 2.2 5.7÷7.8=0.731

Ex. 2.3 2.76÷9.52=0.290

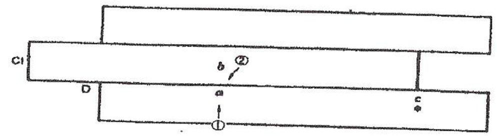


§ 2. MULTIPLICATION

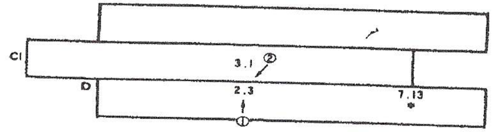
FUNDAMENTAL OPERATION (2) $a \times b = c$

(1) Set the hairline over a on the D scale,

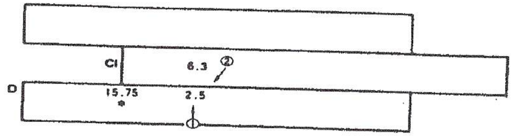
(2) Move b on the CI scale under the hairline,
read the answer c on the D scale opposite the index of the CI scale.



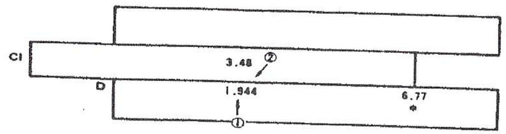
Ex. 2.4 2.3×3.1=7.13



Ex. 2.5 2.5×6.3=15.75



Ex. 2.6 1.944×3.48=6.77



CHAPTER 3. PROPORTION AND INVERSE PROPORTION

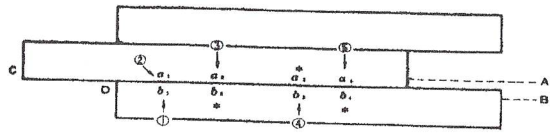
§ 1. PROPORTION

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)

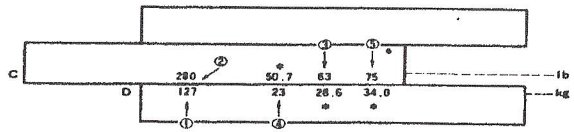
( ) indicates an unknown quantity.



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)

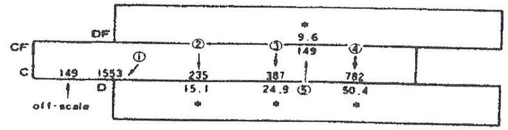


(Note) In calculating proportional problems the C scale must be used for one measurement and the D scale for the other. Intrerchanging the scales is not permitted until the calculation is completed. In Ex. 3.1., the C scale is used for the measurement of pounds and the D scale for that of kilo-grams.

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

In the case of an "off-scale", use the CF scale insteau of the C scale. The answer then is read on the DF scale.



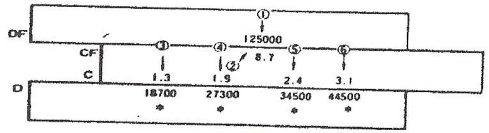
149 is on the part of the C scale which projects from the slide rule and its opposite on the D scale cannot be read. This is called "off-scale". In case of "off-scale", the CF scale is used in place of the C scale and the answer is read on the DF scale.

Using the CF scale in conjunction with the C scale, "off scale" will not occur unless more than one half of the slide protrudes from the body of the slide rule.

Ex. 3.3 Proportional distribution

Distribute the 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



In Ex. 3.3 when 8.7 on the C scale is set opposite 125,000 on the D scale, more than half of the slide protrudes from the body. Therefore, the CF scale is used in conjunction with the DF scale as illustrated.

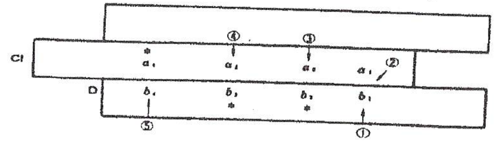
§ 2. INVERSE PROPORTION

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) $A \propto \frac{1}{B}$ $A \times B = \text{Constant}$

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

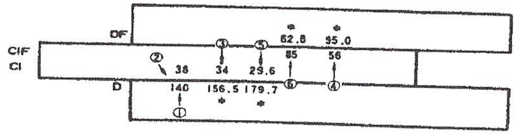
( ) indicates an unknown quantity.



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 $a_4 \times b_4$. Therefore, b_2, b_3, and a_4 can be found by merely moving the hairline of the indicator.

Ex. 3.4 A bicycle runs at 38 km per hour, and takes 140 minutes to go from one town to another. Calculate how many minutes it will take if the bicycle is travelling at 34 km per hour, 56 km per hour, or 29.6 km per hour.

Speed	38 km	34	56	29.6	(62.6)
Time required	140 min	(156.5)	(95.0)	(179.7)	85

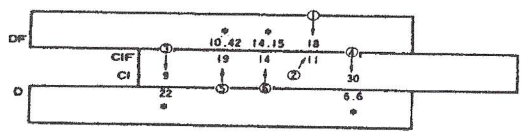


In solving inverse proportion problems, unlike proportional problems, you can freely switch the scales from one to another, but it is preferable to select and use the scales so that the answer is always read on the D or DF scale.

In Ex. 3.4., 56 and 85 run off scale on the CI scale. Therefore the CIF scale can be used instead of the CI scale. Using the CIF scale in conjunction with the CI scale, off scale will not occur unless more than a half of the slide protrudes from the body of the rule.

Ex. 3.5 A job which 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 Ex. 3.5, setting 18 on the D scale opposite 11 on the CI scale, more than one half of the slide protrudes from the body. Therefore, as illustrated above, the DF scale is used in conjunction with the CIF scale.

The DF, CF and CIF scales are generally called "folded scales" and permit efficient multiplication and division of three or more numbers as well as averting off scale positions when working with proportions and inverse proportions. Whereas, the D,C and CI scales are called "normal scales".

CHAPTER 4. MULTIPLICATION AND DIVISION(2)

§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) $(a\times b)\times c=d$, $(a\div b)\times c=d$

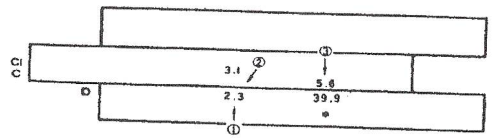
For additional multiplication to follow the calculation $(a\times b)$ or $(a\div b)$, set the hairline over c on the C scale and read the answer d on the D scale under the hairline.

(2) $(a\times b)\div c=d$, $(a\div b)\div c=d$

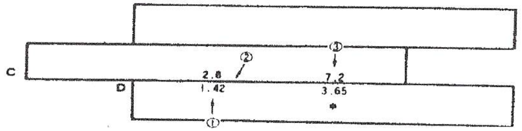
For additional division to follow the calculation $(a\div b)$ or $(a\times b)$, set the hairline over c on the CI scale and read the answer d on the D scale under the hairline.

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 to use the C scale for the additional multiplication and the CI scale for the additional division.

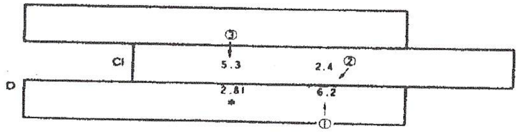
Ex. 4.1 $2.3\times 3.1\times 5.6=39.9$



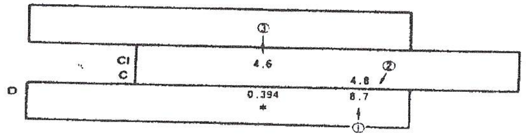
Ex. 4.2 $1.42 \div 2.8 \times 7.2 = 3.65$



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



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

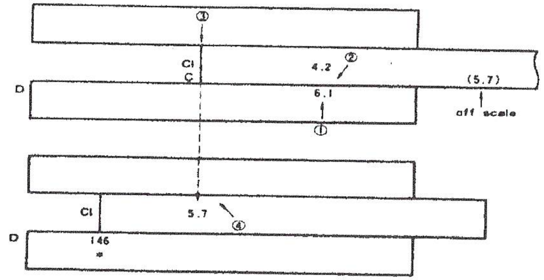


§ 2. OFF SCALE

In multiplication and division calculations, a position on the C or CI scale may occasionally run off scale. There are two methods to solve this off scale problem.

(1) When a position runs off scale, set the hairline over the position on which you read the answer of the first two numbers. Then, move the slide to bring the third number under the hairline.

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



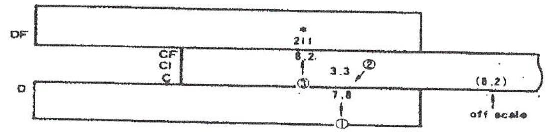
The third number 5.7 on the C scale runs off scale. Set the hairline back over the left index of the C scale and move the slide to bring 5.7 on the CI scale under the hairline. Then, read the answer 146 on the D scale opposite the index of the CI scale. In fact, selection of the scale is exactly the same as in multiplication and division of two numbers.

(2) Folded scales (DF, CF, and CIF)

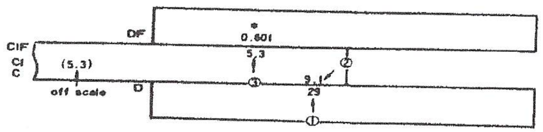
In method (1), one more movement of the slide is necessary compared to when an off scale does not occur. However, the folded scales can be conveniently employed when an off scale occurs.

The folded scales are used in the same manner as in the case of proportion and inverse proportion problems. When an off scale occurs on the C scale the CF scale can be used, and when an off scale occurs on the CI scale the CIF scale can be used. In this case the answer appears under the hairline on the DF scale.

Ex. 4.6 $7.8 \times 3.3 \times 8.2 = 211$

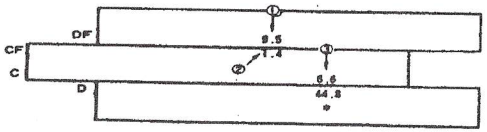


Ex. 4.7 $29 \div 9.1 \div 5.3 = 0.601$



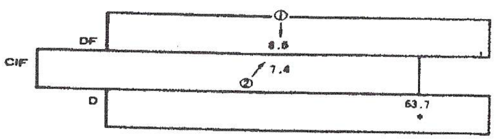
There are some problems in which an off scale will occur on both normal scale and the folded scale. In this case, interchanging the indices in method (1) will be employed; however, the method given below can be also employed.

Ex. 4.8 $9.5 \div 1.4 \times 6.6 = 44.8$



In the above example, when calculating $9.5 \div 1.4$ using the C and D scales, more than one half of the slide protrudes from the rule and, the third number 6.6 runs off scale on both the C scale and CF scale. As shown in the above diagram, calculation can be made by using the DF and CF scales without an off scale occuring.

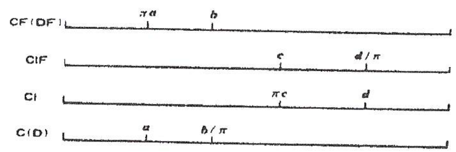
Ex. 4.9 $8.6 \times 7.4 = 63.7$



The DF and CIF scales can also be conveniently used instead of the D and CI scales to solve the above problem. The answer then appears on the D scale.

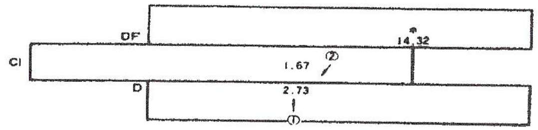
§ 3. MULTIPLICATION AND DIVISION INVOLVING π

The relationship between the normal scales and the folded scales is shown below.

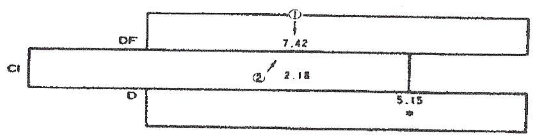


This relationship makes multiplication and division involving π easy.

Ex. 4.10 $2.73 \times 1.67 \times \pi = 14.32$



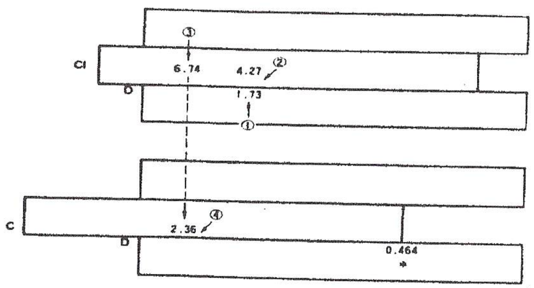
Ex. 4.11 $\dfrac{7.42 \times 2.18}{\pi} = 5.15$



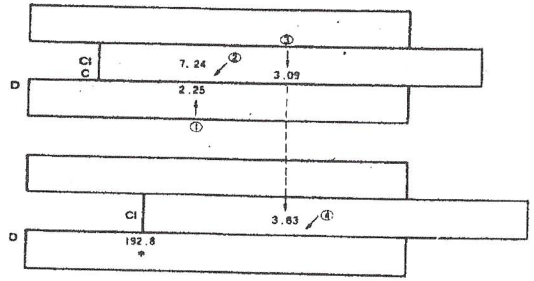
§ 4. MULTIPLICATION AND DIVISION OF MORE THAN FOUR NUMBERS

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 move the slide to accomplish the remaining multiplication or division.

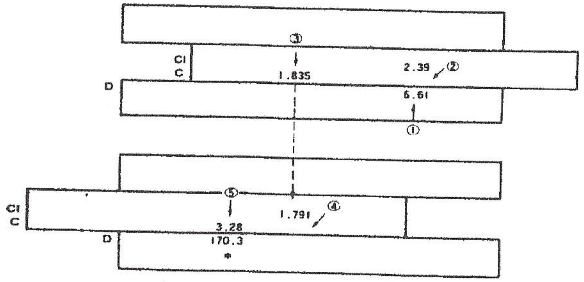
Ex. 4.12 $\dfrac{1.73\times4.27}{6.74\times2.36}=0.464$



Ex. 4.13 $2.25\times7.24\times3.09\times3.83=192.8$



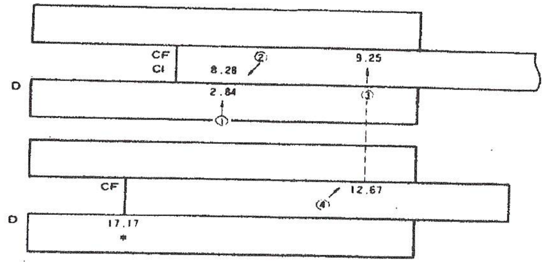
Ex. 4.14 $6.61\times2.39\times1.835\times1.791\times3.28=170.3$



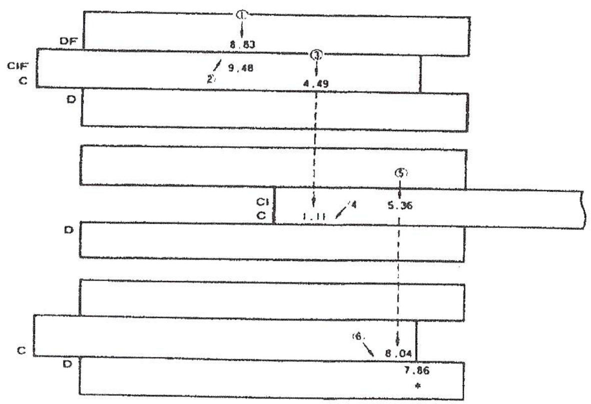
The folded scale can be conveniently used when an off scale occurs. However, once a folded scale is used, it must also be used for the next slide operation. Note that alternate use of a normal scale and a folded scale will result in an incorrect answer.

For example, to calculate 2×3, setting 3 on the CIF scale opposite 2 on the D scale results in 5.92 on the DF scale instead of the true answer 6. If this happens, it indicates a mistake by the operator and not a defect in the slide rule.

Ex. 4.15 $\dfrac{2.84\times8.28\times9.25}{12.67}=17.17$



Ex. 4.16 $\dfrac{8.83\times9.48\times4.49}{1.11\times5.36\times8.04}=7.86$



§ 5. 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 polular will be described here.

(a) 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. $25.3 \times 7.15 = 180.9$

To get an approximate value $25.3 \times 7.15 \rightarrow 30 \times 7 = 210$. Since the significant figures are reao 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. $\dfrac{1.346}{0.00265} = 508$

$\dfrac{1.346}{0.00265} \rightarrow \dfrac{1346}{2.65} \rightarrow \dfrac{1000}{3} \rightarrow 300$

(ii) Reducing fractions

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

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

$\dfrac{\cancel{1.472} \times \overset{3}{\cancel{9.68}} \times 4.76}{\cancel{1.509} \times \cancel{2.87}} \rightarrow 3 \times 5 = 15$

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

(iii) Combination of (i) and (ii)

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

$\dfrac{7.66 \times 0.423 \times 12.70}{0.641 \times 3.89} \rightarrow \dfrac{\cancel{7.66} \times \cancel{4.23} \times 12.70}{\cancel{6.41} \times \cancel{3.89}} \rightarrow 13$

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.

(b) Exponent

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

Ex. $\dfrac{1587 \times 0.0503 \times 0.381}{0.00815} = 3730$

$$\frac{1587 \times 0.0503 \times 0.381}{0.00815} = \frac{1.587 \times 10^3 \times 5.03 \times 10^{-2} \times 3.81 \times 10^{-1}}{8.15 \times 10^{-3}}$$

$$= \frac{1.587 \times 5.03 \times 3.81}{8.15} \times 10^{3-2-1-(-3)}$$

$$= \frac{2 \times 5 \times 4}{8} \times 10^{3-2-1-(-3)} = 5 \times 10^3 = 5000$$

CHAPTER 5. SQUARES AND SQUARE ROOTS

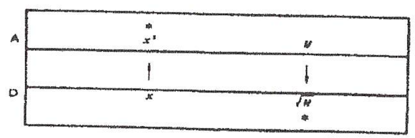
The "place number" is used to find squares and square roots as well as placing the decimal point of squares and square roots.
When the given number is greater than 1, the place number is the number of digits to the left of the decimal point. When the given number is smaller than 1, the place number is 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.

§ 1. SQUARES AND SQUARE ROOTS

The A 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 it consists of two D scales, the A scale is called "two cycle scale" whereas the fundamental C, D and CI scales are called "one cycle scales".

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

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

a) When the answer is read on the left half section of the A scale (1 ~ 10), the "place number" of x^2 = 2 ("place number" of x) − 1

b) When the answer is read on the right half section of the A scale (10 ~ 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 $668^2 = 446000$ ············ The place number of 668 is 3
$= 4.46 \times 10^5$ Hence, the place number in the answer is $2 \times 3 = 6$

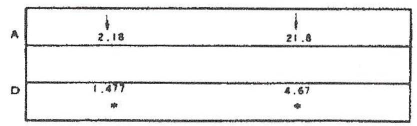
$0.668^2 = 0.446$ ············ The place number of 0.668 is 0 Hence, the place number in the answer is $2 \times 0 = 0$

$0.0668^2 = 0.00446$ ········ The place number of 0.0668 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 digits 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	$\sqrt{0.000218} = 0.01477$



§2. MULTIPLICATION AND DIVISION INVOLVING THE SQUARE AND SQUARE ROOT

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

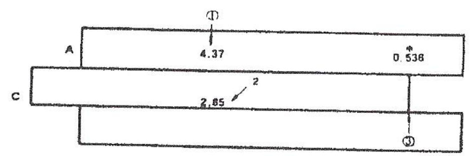
FUNDAMENTAL OPERATION (7)

MULTIPLICATION AND DIVISION INVOLVING SQUARES

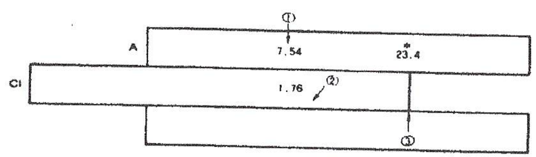
(1) Set the number to be squared on the one cycle scale (C, D or CI) and the number not to be squared on the two cycle scale (A).

(2) Read the answer on the A scale.

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



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



Since the form $a^2 \div b$ cannot be performed by fundamental operation (7), calculate it after changing $a^2 \div b$ into the form $a \times a \div b$.

FUNDAMENTAL OPERATION (8)

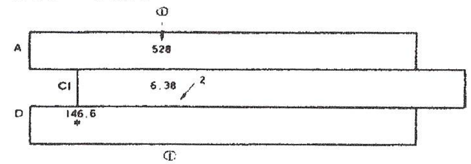
MULTIPLICATION AND DIVISION INVOLVING SQUARE ROOT

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

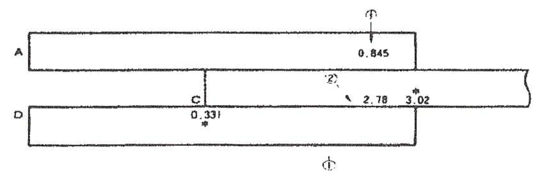
(2) Read the answer on the D scale.

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

Ex. 5.6 $\sqrt{528} \times 6.38 = 146.6$



Ex. 5.7 $\sqrt{0.845} \div 2.78 = 0.331$ $\quad 2.78 \div \sqrt{0.845} = 3.02$



§ 3. THE AREA OF A CIRCLE

A gauge mark (c) is located at 1.128 on the C scale. This can be conveniently used to calculate the area of a circle when the diameter of the circle is given. You can easily find the area of the circle on the A scale by setting the diameter on the D scale and moving the "c" to it.

Ex. 5.8 Find the area of the circle whose diameter is 2.5 cm.

(1) Set the hairline over 2.5 (cm) on the D scale.

(2) Move the "c" on the C scale under the hairline.

(3) Read 4.91 (cm^2) on the A scale under the slide index.

CHAPTER 6. LOGARITHMS AND EXPONENTS

§ 1. COMMON LOGARITHMS

The L scale, which is a uniformly divided scale, is used with the D scale to find the mantissa of common logarithms. The characteristic of the logarithm is found by the place number of the given number. If the place number of the given number is m, the characteristic of the common logarithm found on the D scale is $m-1$.

FUNDAMENTAL OPERATION (9) $\log_{10} x$, antilog$_{10}$ y (10^y)

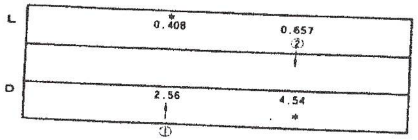
(1) When the hairline is set over x on the D scale, $\log_{10} x$ is read under the hairline on the L scale.

(2) When the hairline is set over the mantissa of y on the L scale, the significant digits of antilog$_{10}$ y is read under the hairline on the D scale.

Ex. 6.1 (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$_{10}$ $\bar{1}.657 = 0.454$



(Note) From the result of $\log_{10} 0.0256 = \bar{2}.408$, the characteristic of $\log_{10}$ 0.0256 is a minus number. This should be rewritten $(-2)+0.408=-1.592$ for further calculation. If the CI scale is used instead of the D scale, the mantissa 0.592 is directly read on the L scale.

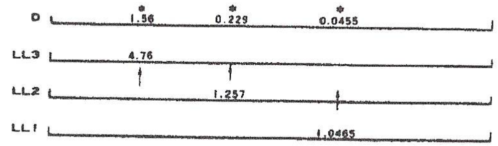
§ 2. NATURAL LOGARITHMS

The LL scale (LL_1, LL_2, LL_3) is used to find natural logarithm. The LL scale differs from the C and D scales, in that it is read with the decimal point in place. Therefore, when the value is larger than 22000 or smaller than 1.01 calculation cannot be directly performed.

(a) HOW TO FIND NATURAL LOGARITHMS

When the hairline is set over x on the LL scale, $\log_e x$ appears on the D scale.

Ex. 6.2 $\log_e 4.76 = 1.56$ $\log_e 1.257 = 0.229$ $\log_e 1.0465 = 0.0455$

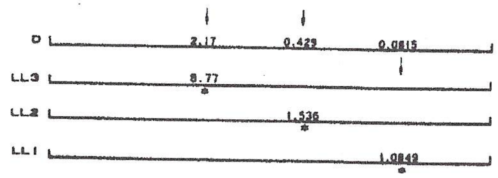


The relationship between the place number of the natural logarithm and the number (1, 2, 3) of the LL scale can be seen from the above illustration.

(b) FINDING e^x

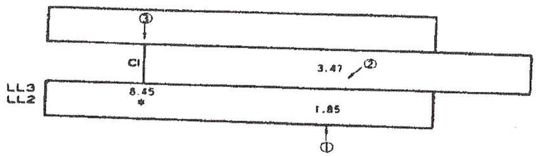
e^x is found on the LL scale when the hairline is set over x on the D scale.

Ex. 6.3 $e^{2.17} = 8.77$ $e^{0.429} = 1.536$ $e^{0.0815} = 1.0849$



For calculating e^{-x}, first find e^x and then find $\frac{1}{e^x}$ by using the C and CI scales.

Ex. 6.5 $1.85^{3.47} = 8.45$



In calculating A^{-x}, find A^x first, and then calculate the reciprocal $\frac{1}{A^x}$.

Ex. 6.6 $0.872^{2.6} = 0.700$

This problem can be converted to $\frac{1}{\left(\frac{1}{0.872}\right)^{2.6}}$ and calculated in the following manner.

(1) Find $\frac{1}{0.872} = 1.147$ (The C and CI scales are used)

(2) Find $1.147^{2.6} = 1.428$ (The LL and CI scales are used)

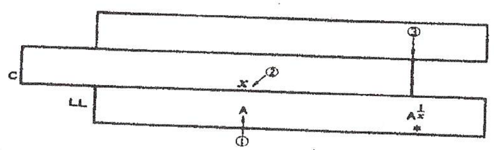
(3) Find $\frac{1}{1.428} = 0.700$ (The C and CI scales are used)

FUNDAMENTAL OPERATION (11) $A^{\frac{1}{x}}$

(1) Set the hairline over A on the LL scale.

(2) Move x on the C scale under the hairline.

Read the answer on the LL scale opposite the index of the C scale.



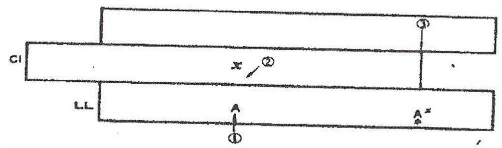
§ 3. EXPONENT

FUNDAMENTAL OPERATION (10) A^x

(1) Set the hairline of the indicator over A on the LL scale.

(2) Move the slide to position x on the CI scale under the hairline.

Read the answer on the LL scale opposite the index of the CI scale.

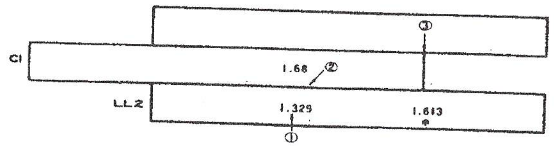


Since the slide rule has three LL scales, you must find on what LL scale the answer will appear. In the calculation of A^x, if x is a number between 1~10, the LL scale on which the answer appears will be determined as follows.

(1) When the slide protrudes to the left, the answer is found on the LL scale having the same number as the LL scale on which A is set.

(2) When the slide protrudes to the right, the answer is found on the LL scale 1 number higher than the LL scale on which A is set.

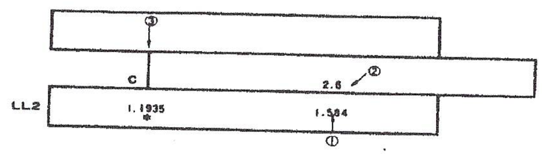
Ex. 6.4 $1.329^{1.68} = 1.613$



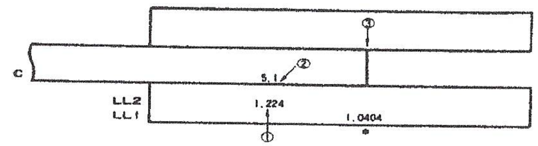
In calculating $A^{\frac{1}{x}}$, where x is a number between 1 and 10, the LL scale on which the answer appears will be determined as follows.

(1) If the slide protrudes to the right, the answer is found on the LL scale having the same number as the LL scale on which A is set.
(2) If the slide protrudes to the left, the answer is found on the LL scale one number lower than the LL scale on which A is set.

Ex. 6.7 $1.584^{\frac{1}{2.6}} = 1.1935$



Ex. 6.8 $1.224^{\frac{1}{5.1}} = 1.0404$



In calculating $A^{-\frac{1}{x}}$, find $A^{\frac{1}{x}}$ first and then obtain the reciprocal $\frac{1}{A^{\frac{1}{x}}}$ as the answer.

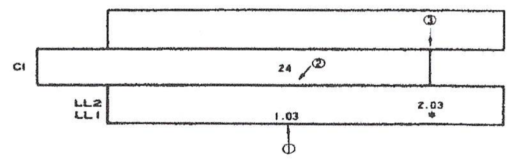
Ex. 6.9 $0.165^{\frac{1}{3.7}} = 0.615$

This problem can be converted to $\left(\frac{1}{\frac{1}{0.165}}\right)^{\frac{1}{3.7}}$ and calculated in the following manner.
(1) Find $\frac{1}{0.165} = 6.06$ (The C and CI scales are used)

(2) Find $6.06^{\frac{1}{3.7}} = 1.627$ (The LL and C scales are used)

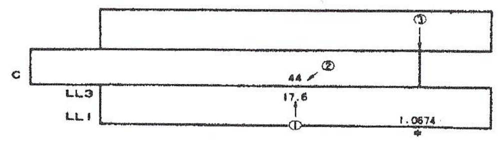
(3) Find $\frac{1}{1.627} = 0.615$ (The C and CI scales are used)

Ex. 6.10 $1.03^{24} = 2.03$



In calculating $1.03^{24} = 2.03$ since 24 is larger than 10, 1.03^{24} is rewritten to $1.03^{2.4 \times 10} = (1.03^{2.4})^{10}$ and read the answer 2.03 on the LL2 scale opposite the position you can read the answer of $1.03^{2.4}$ on the LL1 scale. It is based on the principle that any number on the LL2 scale is the 10th power of the LL1 scale and any number on the LL3 scale is the 10th power of the LL2 scale.

Ex. 6.11 $17.6^{\frac{1}{44}} = 1.0674$ $(17.6^{\frac{1}{4.4} \times 0.1})$



CHAPTER 7. CHEMICAL ENGINEERING CALCULATIONS

§1. ATOMIC WEIGHT AND MOLECULAR WEIGHT

The gauge marks on the Ch scale on the back face of the rule are used to find atomic weight and molecular weight. The following 52 elements and 18 atomic groups, as well as the major elements and important atomic groups in the periodic table, are also included.

Relative / Period	I	II	III	IV	V	VI	VII	VIII	0
1	H								He
2	Li	Be	B	C	N	O	F		Ne
3	Na	Mg	Al	Si	P	S	Cl		A
4	K Cu	Ca Zn		Ti	V As	Cr Se	Mn Br	Fe Co Ni	Kr
5	Rb Ag	Cd		Zr Sn	Sb	Mo	I		Xe
6	Cs Au	Ba Hg		Pb	Bi	W		Pt	
Actinid element		Ra			U				

Atomic groups						
Air	CH_3	C_2H_5	C_6H_5	CN	CO	CO_3
COOH	H_2O	NH	NH_2	NH_4	NO_2	NO_3
OH	PO_4	P_2O_7	SO_4			

All the chemical symbols are arranged in two rows (top row and bottom row) on the slide rule. The top row contains the symbols whose first letter is between A ~ M and the bottom row between N ~ Z with some exceptions. Their atomic weights appear on the D scale.

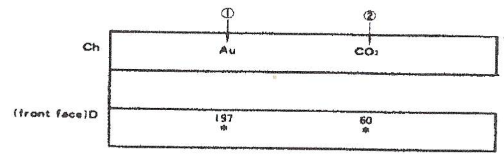
(Placing the decimal point)

The atomic weight of symbols having a line under them can be directly read on the D scale, the weight of symbols without any line must be read by multiplying the reading on the D scale by 10, and the weight of symbols having a line over them must be read by multiplying the reading of the D scale by 100.

This scale is used to find the atomic and molecular weights of elements and compounds and to perform calculations involving them.

Ex. 7.1 (1) What is the atomic weight of Au? Answer 197

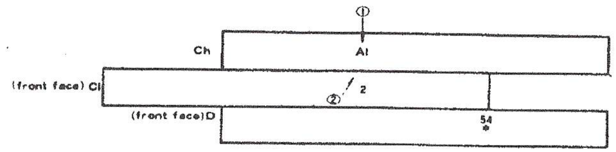
(2) What is the molar weight of CO_3? Answer 60



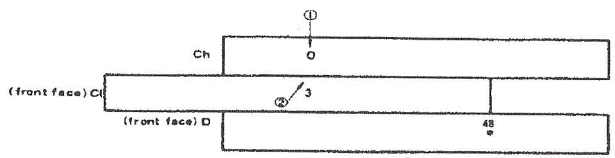
(Note) You can also find the answer on the °K scale on the back of the rule since it is graduated the same as the D scale.

Ex. 7.2 Find the atomic weight of alumina (Al_2O_3)

(1) $Al_2 = 27.0 \times 2 = 54.0$



(2) $O_3 = 16 \times 3 = 48.0$

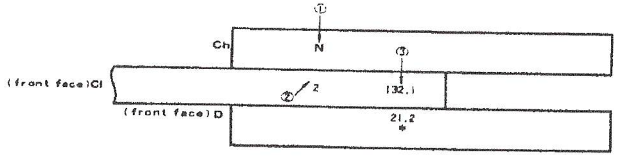


(3) $Al_2O_3 = 54.0 + 48.0 = 102.0$ Answer 102.0

Ex. 7.3 Find the theoretical percentage of nitrogen in ammonium sulfate $(NH_4)_2SO_4$.

(1) Molar weight of $(NH_4)_2SO_4 = (NH_4)\times 2 + SO_4 = 36.1 + 96 = 132.1$

(2) Theoretical nitrogen weight $= \frac{N_2}{(NH_4)_2SO_4} = \frac{N_2}{132.1} = 21.2\%$

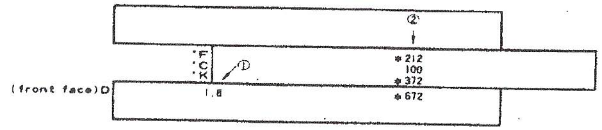


§ 2. CONVERSION OF UNITS

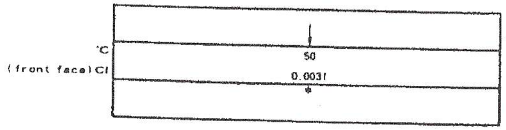
(1) Temperature unit conversion

°F on the back face of the rule indicates Fahrenheit, °C Celsius, and °K Kelvin. Mutual conversion between these can be performed by merely setting the hairline over each of them. If it is necessary to find the absolute Rankine temperature, set the index of the C scale to 1.8 on the D scale in accordance with the formula °R=1.8×°K, and then find °R on the D scale.

Ex. 7.4 100 °C=212 °F=372 °K=672 °R

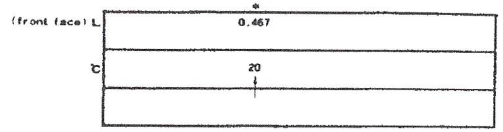


Ex. 7.5 Find $\frac{1}{T}$ of 50 °C. (T: absolute Kelvin Temperature)



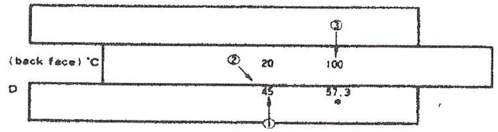
Answer 0.0031

Ex. 7.6 Find log T of 20 °C. Answer 2.467



Ex. 7.7 Expansion of a gas due to temperature rise.

If a gas occupies 45 *l* at 20 °C, how many *l* will it occupy under the same pressure at 100 °C if the pressure is constant? The law of ideal gases $V_2/V_1 = T_2/T_1$ is established.



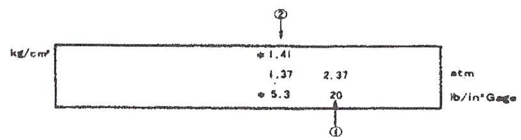
$$V_2 = \frac{V_1 \cdot T_2}{T_1} = \frac{45\times(100+273.16)}{20+273.16} = 57.3\,l$$

(2) Pressure unit conversion

Pressure units are graduated in kg/cm², mmHg, in. Hg Vac., atm, and lb/in² gauge. lb/in² gauge and in. Hg Vac. are gauge pressures based on 1atm = 0. In order to find the value of lb/in² abs from lb/in² gauge, add 1 to the proportional scale (the atm scale). Since the highest graduation on the mmHg scale is 760, it may be necessary to change the place number.

Ex. 7.8 Convert 20 lb/in² abs to another pressure unit.

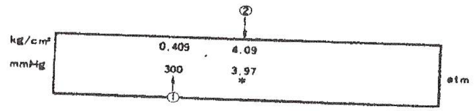
Since 20 lb/in² gauge = 2.37 atm, subtract 1 atm and set the hairline over 1.37 atm.



Answer 20 lb/in² abs. = 1.37 atm = 1.41kg/cm² = 5.3 lb/in² gauge

Ex. 7.9 Convert 15 atm to lb/in^2 abs.
Read the value of lb/in^2 gauge opposite 15+1=16 atm to obtain the answer 220 lb/in^2 abs.

Ex. 7.10 Convert 3000 mmHg to atm.
First divide 3000 mmHg by 10 to obtain 300. Next, set the hairline over 300 on the mmHg scale (equals 0.409 kg/cm^2). Then move the hairline over to the 4.09 on the kg/cm^2 scale. Read the answer 3.97 atm under the hairline on the mmHg scale.

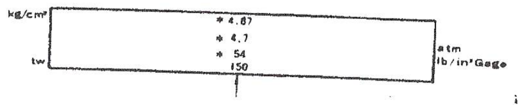


Answer 3.97 atm

§3. VAPOR PRESSURE OF WATER

The five types of pressure graduations which correspond to the temperature of water tw all indicate saturated vapor pressure. Conversely, the boiling point of water can be found at any desired pressure. The portion of the tw scale to the left of 0°C shows the temperature of ice and the portion to the right, which is 374.16°, shows the critical temperature of water. That is, water does not exist in liquid from above the critical temperature.

Ex. 7.11 Find the saturated pressure of steam at 150 °C.



Answer: 4.7 atm (=4.87 kg/cm^2 =54 lb/in^2 gauge)

Ex. 7.12 At what temperature does water boil under a pressure of 30mmHg?
29°C can be found on the tw scale by setting the hairline over 30 mmHg.

§ 4. DENSITY UNIT CONVERSION

There are weight percent, volume percent, and molar percent in expressing chemical composition. There are two ways of expressing density; one is based on the total amount of the mixture and the other is based on the amount of a certain component in the mixture. The Xw and X scales in the two component system are graduated to permit conversion of these different systems. These scales can also be used for other applications.

(1) Molar fraction, weight fraction, and volume fraction conversion

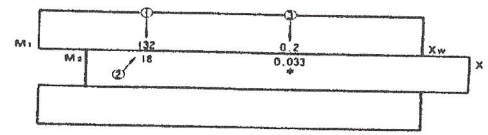
Any mixture consists of two components, the first and the second.
The molar fraction of the first component (1/100 of the molar percent) is set on the X scale, the weight fraction on the Xw scale, and the volume fraction on the Xv to obtain the following relationships.

$$\frac{X}{1-X} \cdot \frac{M_1}{M_2} = \frac{X_W}{1-X_W} \quad \cdots\cdots (1)$$

$$\frac{X_V}{1-X_V} \cdot \frac{\rho_1}{\rho_2} = \frac{X_W}{1-X_W} \quad \cdots\cdots (2)$$

M_1 and ρ_1 represent the molecular weight and density of the pure constituent of the first component and M_2 and ρ_2 represent the same thing for the second component. The relationship in formula (2) is not applicable when the volume changes in accordance with the mixture.
The four graduations on the M_1, M_2, Xw and X scales show the relationship given in formula (1) above. The relationship in formula (2) can be obtained by substituting ρ_1 and ρ_2 for M_1 and M_2.
M_1 and M_2 can be easily read by changing the place number. However, if the left end of the M_1 scale is read as 10, then the left end of the M_2 must also be read as 10.

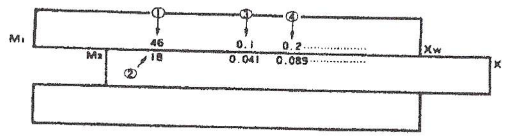
Ex. 7.13 Find the molar % of 20 wt% of an ammonium sulfate-water solution. Taking ammonium sulfate $(NH_4)_2SO_4$ as the first component and water (H_2O) as the second component; M_1=132.1 and M_2=18.0. Set 18.0 on the M_2 scale to correspond to 132.1 on the M_1 scale considering the left end of both scales as 10. Then read the value on the X scale corresponding to 0.2 on the Xw scale.



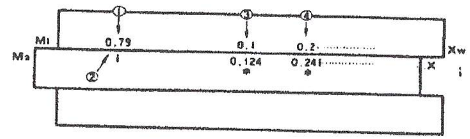
Answer 3.3 mol %

Ex. 7.14 Convert an alcohol-water solution at 15.56 °C to molar % and vol % at weights of 10, 20, 30, 40, 50, 60, 70, 80, and 90.
The molecular weights of pure alcohol and water are 46.05 and 18.02 respectively. Their density at 15.56°C is 0.794 and 0.999.

(a) Set $M_1=46$ and $M_2=18$ (the left end of the scales is assumed to be 1), the molar % versus weight can now be found by merely moving the indicator.



(b) Set $\rho_1=0.794$ (M_1 scale) and $\rho_2=1$ (M_2 scale). The vol % (X scale) can now be found from the wt % (Xw scale) by merely moving the indicator.



A summary of the results discussed up to now are shown in the below table. The calculated value of vol % will differ slightly from the true value since the volume of alcohol and water is reduced by the mixture.

	Wt %	10	20	30	40	50	60	70	80	90
	mol %	4.1	8.9	14.1	20.7	28.0	36.9	47.6	60.6	77.9
	Vol %	12.4	24.1	35.1	45.9	56.0	65.7	74.9	83.6	92.0
Actual	Vol %	12.4	24.1	36.0	47.1	57.7	67.5	76.8	85.3	93.1

(2) The gas-liquid balance relationship of an ideal solution.

The following equation expresses the relationship between liquid phase x (molar fraction of the component having the smaller volatility) and gaseous phase y (molar fraction of the component having the larger volatility) of an ideal solution conforming to Raoult's law and consisting of 2. components at a balance relation.

$$\frac{X}{1-X}\cdot\frac{P_1}{P_2}=\frac{y}{1-y}$$

Where: P_1=Vapor pressure of the more volatile pure component
P_2=Vapor pressure of the less volatile pure component

Since the above formula is the same as formula (1), this slide rule provides the continuous relationship x−y.

Distillation is usually performed under a certain pressure. Therefore, the composition of the liquid phase, as well as the boiling point, changes due to a loss in the more volatile component, and a simultaneous enrichment of the less volatile component.

However, since the proportion changes very little, the geometric average of the specific volatility at the boiling point when each component is pure is used and the composition of the solution can be generally considered to be constant over the entire range.

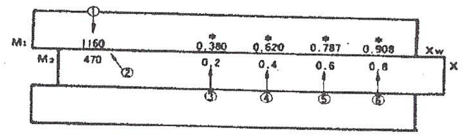
The boiling point of each component at the pressure of distillation can be set as t_{b1} and t_{b2}. Let P_1 represent the geometrical average of the vapor pressure of the first component (that having the higher volatility) and P_2 represent the same thing for the second component. If $\bar{P}_1$ is set on the M_1 scale and $\bar{P}_2$ is set on the M_2 scale, gaseous component y will appear on the Xw scale and liquid component X will appear on the X scale.

Ex. 7.15 Find the balance relationship of benzene and toluene at a pressure of 1 atm.

At 1 atm, the boiling point of benzene (t_{b1}) is 80.2 °C and that of toluene is 110.8 °C (t_{b2}). The vapor pressure of each pure component at that temperature is as follows:

	Benzene	Toluene
Vapor pressure (mmHg) at t_{b1}(80.2°C)	760	292
Vapor pressure (mmHg) at t_{b2}(110.8°C)	1770	760
Geometric mean	$\bar{P}_1$ = 1160	$\bar{P}_2$ = 470.5

Set $\bar{P}_1$ over the M_1 scale and $\bar{P}_2$ over the M_2 scale, the x—y relationship can be continuously obtained in proportion to the X and Xw scales. Therefore, only read the required part. An example is given below.



x	y
0.2	0.380
0.4	0.620
0.6	0.787
0.8	0.908

(3) LOGARITHMIC MEAN

In the field of chemical engineering, there are a lot of cases in which we accomplish the logarithmic mean, for example finding the logarithmic mean temprature difference between a heating body and a heated one. The logarithmic mean can be calculated by the following equation.

a indicates here the initial value and b does the final value.

Ex. 8.16

The initial temprature difference between a heating body and a heated one: 150°C

The final temprature difference between a heating body and a heated one: 30°C

In this case, how high is the logarithmic mean temprature?

(1) Operating the mmHg scale and LMa/b scale in the way like the below chart, find a/b = 5

(2) Leaving the center scale as it is, move the hairline over 5 on the lm (a : b) scale and read the answer under the hairline on the atm scale.

Answer 75°C

(4) Gauge marks

The °K scale has the following gauge marks and it can therefore be conveniently employed in a wide range of applications.

R_1 = 1.986 cal. degr^{1}. mole^{-1}	Molecular gas constant	
R_2 = 62.36 l. mmHg. degr^{1}. mole^{-1}		
R_3 = 0.08205 l. atm. degr^{1}. mole^{-1}		
V_0 = 22.414 l. mole^{1}	Standard molecular volume of an ideal gas	
F = 26.8 amp. hr. g-equiv^{1}	Faraday constant	
k = 273.16/760 = 0.3594 °K.mmHg^{1}	Volume correction factor of an ideal gas	
J = 4.185 joule. cal^{-1}	Work equivalent of heat	