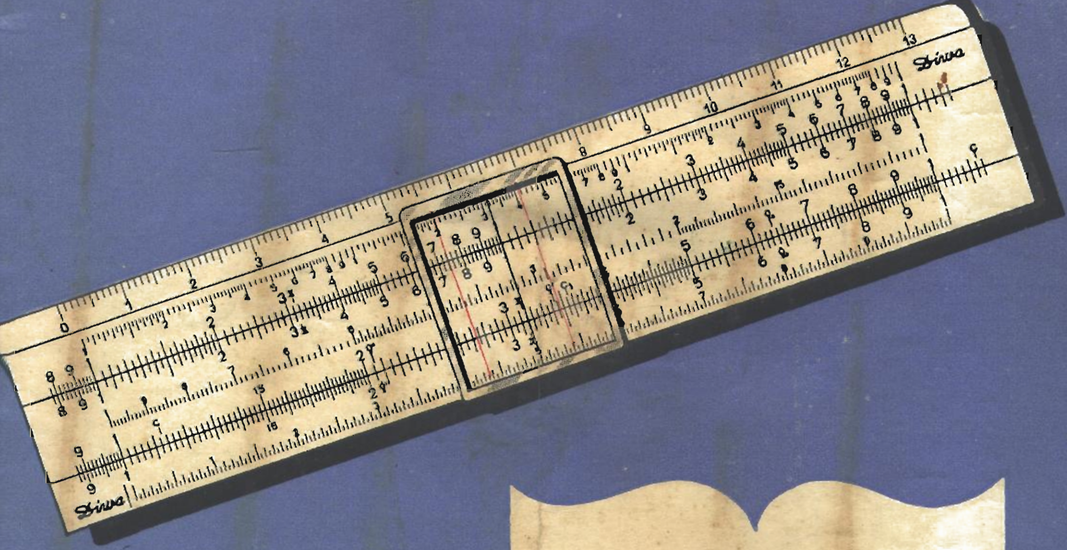
Diwa

engraved

SLIDE RULES



Diwa

MANUFACTURING COMPANY

COPENHAGEN . GENTOFTE . DENMARK

INSTRUCTIONS FOR USE

Diwa

SLIDE RULES

Instructions for the use of the models

TECHNICAL 201, LOG-LOG 101 and ELECTRO 111

2nd ed.

Published 1949 by the
DIWA MANUFACTURING COMPANY
Copenhagen, Gentofte, Denmark

As an invention the slide rule is quite old. Only a few years after the publication of Henry Brigg's treatise on common logarithms the first slide-rule was constructed by Winsgate, England, in 1627, so it might seem somewhat difficult to understand why it should take 300 years for the slide rule to come into general use; this is but mainly due to the fact that only recently technical skill has reached the high level required for slide-rule production. The crude handmade slide rule of 300 years ago little resembles the DIWA slide rule af to-day, the manufacture of which calls for machinery and materials unknown even 30 years ago.
Although it is an advantage to have a fair knowledge of the fundamental theory of the slide rule, this is unnecessary for the practical application to general engineering and business calculations, just as it is possible to drive a car without knowledge of the basic principles of its construction.
No slide rule can be used for addition or subtraction, and such calculations which can be made on a slide rule have only a certain degree of accuracy; this, however, is sufficient for technical purposes, and after acquiring some skill, differences can be reduced to about 1 per mill.

Various types of the DIWA slide rule are available for different purposes. The following instructions deal with TECHNICAL 201 — the most commonly used slide rule. The slide rule consists of 3 main parts:

THE STOCK OR BODY, has 4 logarithmic scales K, A, D and L on the face (see fig. 3). On the sides are two linear scales divided into 1/16 inches and millimetres. The reversible center SLIDE has on the face three scales B, CI and C, and on the back three trigonometrical scales S, S & T, and T.

The CURSOR, (runner or indicator) — is a transparent sliding frame with one black and two red hairlines engraved.

Fig. 1.

With a single exception all scales are divided logarithmetically and the divisions decrease from left to right. The principal scales C & D (fig. 1) cover one logarithmic cycle, i. e., all numbers between 1 and 10. As seen from the figure the distance between 8 and 9 is much smaller than the distance between 1 and 2, consequently the subdivisions at the right end of the scale do not have the same value as the subdivisions at the left end of the scale.

Each logarithmic cycle is divided into 10 parts corresponding with the first significant figure in any number (fig. 2), each of these major divisions is subdivided into 10 parts corresponding with the second significant figure. In the interval from 1 to 2 these subdivisions are marked by the numbers 1—9 corresponding with 11, 12, 13, 14, and so on.
The left third of the scale is furthermore divided into ten tertiary parts, each of these has the value of "one" corresponding with the third significant figure, 1, 2, 3, and so on; the center part is divided into five parts, each of these has the value of "one" corresponding with the third signifi-figure 2, 4, 6 and 8; the right third is only subvided once, the line corresponding with the cipher 5. Fig. 2, shows several examples of how to read the scale.

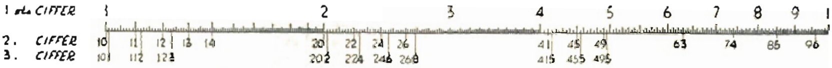


Fig. 2

To read three or four significant figures it is necessary to infer or interpolate between the tertiary divisions. 253 for instance lies between 252 and 254. 1253 lies between 125 og 126. After some practise it is possible to infer 1/10 of a division.
It must be noted that by setting and reading the slide rule no attention is paid to the decimal point or to the total number of figures. The decimal point is not settled until the final result has been reached. The numbers 13200, 132, 1,32 and 0,0132 have the same setting as only the ciphers and the sequence of these are considered. Before the slide rule is taken into use it is necessary to familiarize oneself with the various settings and readings. As the scales A, B and K are divided into more logarithmic cycles than the fundamental scale D, the subdivisions of these scales do not have the same value, although the general trend is the same.
The scales on the face of the slide rule are used as follows:
SCALE C and D (Fundamental scales). These two scales, which are placed closely together on the body and on the slide, are exactly alike and used for multiplication, division, and other problems of this kind. The scale has a length af 250 mm and covers one logarithmic cycle.
SCALE A and B (Squares and square roots) are close together on the upper part of the body and the slide, covering two logarithmic cycles, each 125 mm long. They may either be used instead of the scales C and D for multiplication, division, etc., or together with the scales C and D for problems af squares and square roots.
SCALE K (Cubic scale). The top scale of the body covers 3 logarithmic cycles, and is used for reading cubes and cube roots.
SCALE L (Logarithmic scale). On the lower part of the body is a uniformly

graduated scale. Combined with scale D it is used for finding common logarithms of numbers.

SCALE CI (Reciprocal scale) on the slide is an inverted scale exactly like the scale C, the divisions running from right to left. Opposite each number on scale C a corresponding number is found on CI; the product of these numbers equals 1.

On the reverse side of the slide are three scales used for solving trigonometrical problems:

SCALE S which in conjunction with scale C gives the values of the trigonometric function "sine" from 0.1-1 (sin 5° 43' — sin 90°).

SCALE T which likewise in conjunction with scale C gives the values of the trigonometric function "tangent" from 0,1-1 (tg 5° 43' — tg 45°).

SCALE S & T. Since the values for "sin" and "tg" for small angles are nearly equal, this scale is common for values between 0,01 and 0,1 (35' — 5° 43').

To insure readability the scales have no identification marks, but until a certain practise has been attained, pencil marks may be used in accordance with fig. 3.

INSTRUCTIONS FOR USE

To simplify explanations we will call the number 1 graduation mark at the beginning of all scales the left-hand index, and the number 1 graduation mark at the end of any scale the right-hand index.

MULTIPLICATION: To multiply one number by another place the left or the right index of the scale C over one of the numbers on the scale D, and read the answer on the D scale under the other number on the C scale.

a) 3 × 16. Opposite 3 on D set the left index of C, find 16 on scale C and read the answer (48) on scale D.

b) 6,2 × 0,35. Opposite 62 on scale D set the right index of the slide, use the indicator to find 35 on scale C and read the answer (217) under the hair-line on scale D. The problem is solved without regard to the decimal point, but by mental calculation it is found to be 2,17. Multiplying three or more factors it is unnecessary to write down the result of each single multiplication, but the cursor is used to indicate and keep it temporarily fixed.

c) 3,2 × 4,5 × 36. Place the right index over 32 on scale D, move the indicator to 45 on scale C without noticing the answer (144), set the left index under the indicator-line, and find the answer (518) on scale D opposite 36 on scale C. The exact result is 518,4, and the error consequently less than 1/1000.

DIVISION: To divide one number by another set the divisor on scale C against the dividend on scale D — using the cursor — and read the answer on scale D either under the right or the left index. This operation is the

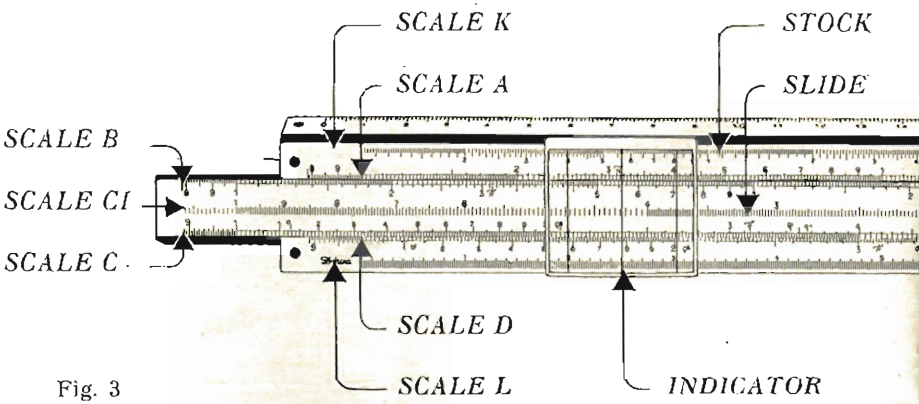


Fig. 3

reverse of multiplication; the result may be controlled by multiplying with the divisor; the answer being the dividend.

a) 18 ÷ 3. Find 18 on scale D, place 3 on scale C opposite this, and read the answer (6) under the right index.

b) 58 ÷ 25. Find 58 on scale D, place 25 on scale C opposite this and read the answer (232) on scale D without regard to the decimal point. The right answer is easily seen to be 2,32.

COMBINED MULTIPLICATION AND DIVISION: Where an expression of the form $\frac{7 \times 5}{6}$ is to be evaluated, this may be done in one operation. Start by dividing 7 by 6 — setting 6 on scale C opposite 7 on scale D — without taking note of this intermediate result the combined answer (583, i. e. 5,83) is found on scale D opposite 5 on scale C.

THE NUMBER OF DIGITS in a number larger than 1 is the number of figures to the left of the decimal point. In a decimal fraction the number of digits is a negative number equal numerically to the number of zeros between the decimal point and the first significant figure.

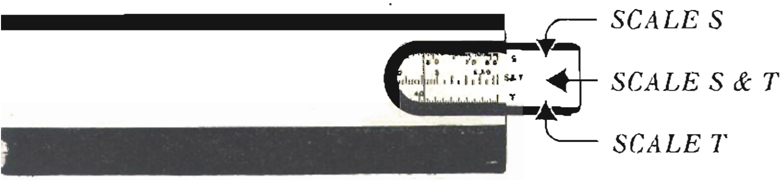
Examples: Number..........	637	63,7	6,37	0,637	0,0637	0,00637
Number of digits .	3	2	1	0	— 1	— 2

The decimal point in the result can be determined by the following DIGIT-RULES:

a) When the slide projects to the left:

Multiplication: When two or more factors are multiplied together using the D and C scales, the number of digits in the product is equal to the sum of the numbers of digits in the factors: 605 × 22 = 13310 (3 + 2 = 5).

Division: The number of digits in the quotient is equal to the number in the dividend minus the number in the divisor: 242 ÷ 4 = 60,5 (3 — 1 = 2).



b) When the slide projects to the right the number of digits in the divisor or in one factor is counted 1 less than according to the rules above.

Multiplication: $15 \times 49 = 735$ $(2 + (2 - 1) = 3)$.
Division: $8{,}25 \div 500 = 0{,}0165$ $(1 - (3 - 1) = -1)$.
When deciding the decimal point according to the digit rules the extensions over the right and left index must not be used: In division this also applies to the right index on scale D on the stock.

SQUARES AND CUBES.

Opposite any number on the scale C or D read its square on scale A or B or its cube on scale 3, using the hairline on the cursor for exact identification.

a) $3{,}2^2$ Place the cursorline over 32 on scale D, and read the result (102 = 10,2) on scale A opposite 3,2.
b) $3{,}2^3$ Place the line over 32 on scale D, and read 327 = 32,7 on scale 3 opposite 3,2.

SQUARE-ROOTS. The square-root of a number is found as follows: opposite the number on scale A, read the square root on scale D using the cursor; use the left half of D, if the number has an ODD number of digits, and the right half, if the number has an even number of digits before the decimal point.

a) $\sqrt{169} = 13$ number of digits: ODD, left half.
b) $\sqrt{64} = 8$ number of digits: EVEN, right half.
c) $\sqrt{640} = 25{,}3$ number of digits: ODD, left half.

AREAS. The area of a square having a sidelenght "a" is "a^2". By placing the cursorline on any given number on scale D indicating the side length of a square the area may be read on scale A. The area of a circle is:

square of diameter × 0,7854. With reference to scale A the number 7854 is indicated on the cursor by two red lines. Placing the centerline of the cursor over any number on scale D indicating the diameter of a circle, the area of this circle is found on scale A under the lefthand red line. Conversely, if the area is known, the diameter is found by placing the centerline over the area on scale A, and reading the diameter on scale D under the righthand red line.

a) Sidelength or diameter: 3 ft. Area of square: 9 sqft. Area of circle: 7,08 sqft.

b) Area 13 sq. inches. Sidelength of square: 3,6 inches. Diameter of circle: 4,08 inches. Use the left or the right half of scale A according to the rules mentioned under "square-roots".

CUBE-ROOTS. The cube-roots of a number is found as follows: Opposite a given number on scale K read the cube-root on scale D using the cursor. If the number of digits in the given number can be divided by 3, i. e. 0,3,6 etc. use the right third of the scale, if by dividing the number of digits with 3 the remainder is 2, i. e. — 1, 2, 5, 8 use the middle third. If the remainder is 1, (— 2, 1, 4, 7, etc.) use the left third of the scale K.

a) $\sqrt[3]{8000}$	= 20	number of digits:	4	divided by	3, remainder	1
b) $\sqrt[3]{64}$	= 4	—	— 2	—	3	— 2
c) $\sqrt[3]{125}$	= 5	—	— 3	—	3	— 0
d) $\sqrt[3]{640}$	= 8,62	—	— 3	—	3	— 0

RECIPROCALS. Opposite any number on scale C read its reciprocal on scale CI (red).

a) Opposite 2 on C read 1 ÷ 2 = 0,5 on scale CI.

b) Opposite 0,45 on C read $\frac{1}{0,45}$ = 2,22 on scale CI.

Note that the subdivisions on scale CI read from right to left.
Besides permitting the reading of reciprocal numbers, the CI scale can be used in multiplication and division in conjunction with the D scale.

MULTIPLICATION. To multiply 2 numbers set the cursor on one of the factors on scale D, move the slide so that the other factor on the CI scale is under the hairline, and read the product on the D scale under the right or the left hand index.

a) 27 × 31, set the cursor on 27 (scale D), bring 31 on scale CI under the hairline, and read the product (837) on scale D, under the right hand index.

DIVISION: is the reverse operation.

b) 42 ÷ 2,5, set the right index over 42 on scale D and read the result (16,8) on this scale under 25 on scale CI using the cursor.

TRIGONOMETRY: It is assumed that the reader is familiar with common trigonometrical problems.

SINE. If the value of any angle on the sine scale S is set opposite the index line in the slot on the reverse side of the rule, the right index on scale D will coincide with the sine value read on scale C.

a) sin 35°; read 0,573 on scale C.

For angles between 35' — 5° 43' use the S & T scale, which is common for both sine and tangent, reading the numerical values as mentioned above. The decimal point is determined in such a manner that the value is 0,01—0,1.

b) sin 4° = tan read 0,0698 on scale C.

TANGENT. Set the angle value on scale T opposite the index line in the slot on the reverse, and read the numerical value of the tangent on scale C over the left hand index. The numerical values of tg 5° 42'—45° are 0,1—1.

a) tg 18°; read 0,325 on scale C.

To find the tangent of an angle between 45°—84° use the formula $\tan A = \frac{1}{\tan (90 - A)}$

To find the COSINE use the fact that cos A = sin 90 — A.

COTANGENT is found by the formula $\cot A = \frac{1}{\tan A}$

LOGARITHMS. The scale L is used to decide the mantissa or decimal part of the common logarithm of a number.

Opposite a given number on scale D read the mantissa of its logarithm on scala L. The caracteristic is decided by use of rules with which the reader is assumed to be familiar. Determining the number, when its logarithm is known, is of course the reverse operation, using the characteristic to decide the number of digits, the mantissa to decide the numerical value.

a) log 32; read 505 giving the logarithm as 1.505.

b) log x = 2,70; read x = 501.

The following special marks are found on the slide rule; $\pi = 3,1416$ (ratio of circumference to diameter of circle).

$c = \sqrt{\frac{4}{\pi}} = 1.128$ (scale D).

$c_1 = c \times \sqrt{10} = 3,568.$

$\varrho' = 3428.$

$\varrho'' = 206265.$

$\varrho_{,,} = 636620.$

Unindicated line on scale B: $\frac{\pi}{4} = 0,7854.$

These elementary instructions in the use of the slide rule are intended for the beginner who has no previous training in mathematics. It is impossible in brief to account for all the different uses of a slide rule, but more complete books of instruction are available, in which extensive information can be found, including the fundamental theory of the slide rule.

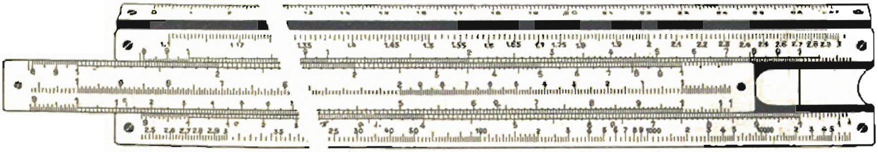


Fig. 4

MODEL 101, LOG-LOG

The DIWA LOG-LOG slide rule differs from the TECHNICAL 201 only in the following respects:

The top and lower scales K & L are substituted by two LOG-LOG scales L_1 & L_2, covering respectively the values $e^{0.1}$ - e^1 and e^1 - e^{10}, and giving together all equations of the form a^n & $a^{1/n}$ for values between 1.1 and 53000. The cubic scale (K) is transferred to the vertical edge of the stock, and the uniformly divided scales L (common logarithms) and 1/25 centimetres are left out.

Multiplication, division, squares, square roots, cubes, and cube roots, and all trigonometrical calculations are performed in the same way and as easily as on the DIWA TECHNICAL 201. On the other hand it is necessary to be fully aquainted with the use of the common slide rule and with basic mathematics to get the full benefit of a LOG-LOG slide rule.

The two LOG-LOG scales are to be considered as one continuons scale divided into two parts. The scales are so arranged that on the upper part $e^{0.1}$ = 1.105 coincides with the left hand index 1, and e^1 = 2,7183 with the right hand index; the lower part has e^1 = 2,7183 at the left hand index, and e^{10} = 22026 at the right hand index. Extensions enable readings from 1.1 to 53000, this being sufficient for most purposes. The LOG-LOG scale can be used in conjunction with the scale D only, and does not cover numbers outside the above mentioned range.

NATURAL LOGARITHMS AND ANTI-LOGARITHMS.

Against any number on the LOG-LOG scale the natural logarithm of this number is found and vice versa.

Against	1.4	on scale	L_1	read	l_n 1.4	=	0,337	on scale	D
—	140	—	L_2	—	l_n 140	=	4,94	—	D
—	0,2	—	D	—	$e^{0.2}$	=	1,221	—	L_1
—	2	—	D	—	e^2	=	7,39	—	L_2

The common logarithm is found by multiplying the natural logarithm by 0.4343.

POWERS AND ROOTS.

With the aid of the cursor and the scale D all powers and roots of the form a^n and $\sqrt[n]{a}$ can be evaluated. Neither n nor a need be a whole number. Using the basic logarithmic formulas $\ln a^n = n \cdot \ln a$, and $a^n = \text{anti-ln}\,(n \cdot \ln a)$, the calculations are performed as follows:

POWERS: using the cursor find the number "a" on one of the LOG-LOG scales, thereby deciding the ln of the number read on scale D; bring the right or left index of the slide under the cursor line and multiply with the exponent, finding the answer on the LOG-LOG scale by setting the cursor-line against the exponent.

EXAMPLES:

$1.4^2 = 1.96$. Bring the left index of the slide rule under 1.4 on scale L_1 (using the cursor), and read the answer on scale L_1, against 2 on scale D.
$1.4^{2,2} = 2,1$. Proceed as above but read the answer against 2,2 on scale D.
$1.4^{5,1} = 5,58$. Bring the right index of the slide under 1,4 on scale L_1 (using the cursor) and read the answer on scale L_2, against 5,1 on scale D.

ROOTS.

Roots of the form $\sqrt[n]{a}$ can be written as $a^{\frac{1}{n}}$. To find a root of any number proceed as under powers, but instead of multiplying divide by the exponent.

Example:

$\sqrt[4.6]{6,3} = 6,3^{1/4,6} = 1,491$. Set the cursor against 6,3 on scale L_2, bring 4,6 on scale C under the cursor-line, and read the answer on scale L_1 above the right hand index on the slide. The reciprocal scale CI can be used instead of the scale C, the proceedings by powers and roots being reversed. If it is necessary to operate with numbers outside the normal range of the LOG-LOG scale, it will often be possible to find the result by simple circumscriptions as:

$0.7^{1,35} = 7^{1,35} \div 10^{1,35} = 13,8 \div 22,4 = 0,615.$

The two powers are found as above and the results divided.
Circumscriptions of this kind may sometimes be used to reach a greater accuracy in the result than the small divisions of the scale L_2 permit, although it must be remembered that the intermediate results are found with the normal inaccurateness.

Example:

$6^{4,7} = 2^{4,7} \cdot 3^{4.7} = 26 \cdot 174 = 4530\ (4542).$

MODEL 111, ELECTRO.

The DIWA slide rule ELECTRO 111 is conformably to the LOG-LOG slide rule, but is equipped with additional constants, indicators, and with two more scales of special interest to electrical engineers.
The two new logarithmic scales are placed in the bottom of the stock, and read by means of a metal indicator at the left end of the slide.
The lower of the scales is used to calculate loss of potential, current strength, length, or section of lead, when three of these factors are known.
The loss of potential in a copper-wire lead with direct current or induction-free, alternating current is:

$e = \frac{J \cdot L}{c \cdot q}$ where e = loss of potential in volt.
J = current strength in amps.
L = length in metres of single lead.
q = area of copper section in square millimetres.
c = 28,7 = specific conductivity of copper . 0,5.

Example: Find the loss of potential for a copper lead of 10 sq. mm section and 75 m in length, current strength 12 amps.
Using the scales A and B, multiply 12 by 75, divide the result by 10 and read the answer 3,13 volt at the end of the slide on the voltage loss scale.
If this loss of voltage is too high, it is easily seen by moving the slide rule indicator to f. i. 2 volt that a 16 (15,7) mm^2 lead is to be used.
The upper scale in the bottom marked DYNAMO and MOTOR is used for calculating the efficiency, the output, or the horse-power of dynamos and motors.
On account of the difference between one horsepower in British measure (1 HP = 550 ft-lb per sec. = 746 watts) and one horsepower in the metric system (1 HP = 75 kgm = 736 watts) the indicator to the scale DYNAMO and MOTOR and the corresponding mark on the slide-rule designed for the British market differ slightly from those on the models for the metric market.
EFFICIENCY OF DYNAMOS. Determine the efficiency of a dynamo using 120 horsepower with an output of 80 kW. Using the scales A and B divide 80 by 120 and read the answer 89,5 % by means of the indicator on the slide.
Corresponding values of horse-power and output in kW can be found by setting the indicator on the slide on any fixed efficiency.
Example: Efficiency 85 % gives HP/kW: 20/12,7 30/19,1 40/25,4 80/50,8.
EFFICIENCY OF MOTORS: Determine the efficiency of a motor of 35 HP with an input of 30 kW. Divide the input by the HP using the scales A and B and read the answer 87,0 on the MOTOR-scale at the indicator.
The constants 28,7 (specific conductivity of copper × 0,5), 746 (HP/watts) and $1/\pi = M = 0{,}3183$ are marked on the scales 2-2. These scales moreover have the markings: "10 amps.", "kw", "10 m 10 sq. mm" and "HP" as a reminder when making the aforementioned calculations.

MANUFACTURING COMPANY

Dinva

DENMARK

KAJ ORBOE. HELLERUP