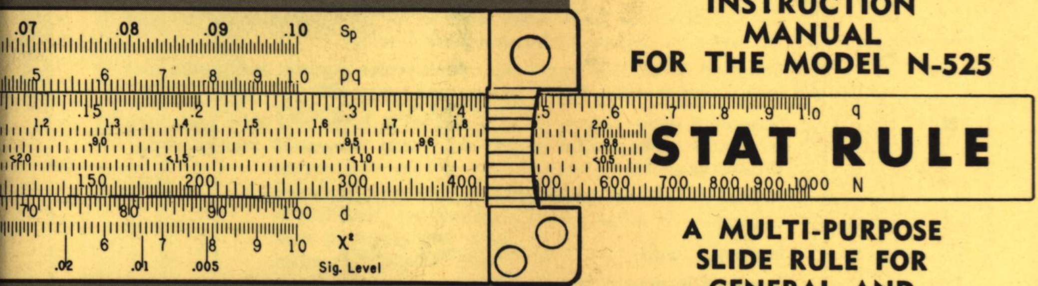
PICKETT

COMPLETE INSTRUCTION MANUAL FOR THE MODEL N-525



A MULTI-PURPOSE SLIDE RULE FOR GENERAL AND STATISTICAL USE

"A TRULY PROFESSIONAL MANUAL & RULE"

by WILLIAM HARRIS, Ph.D.
HUMAN FACTORS RESEARCH, INC.
LOS ANGELES, SANTA BARBARA

Price **$1.00**

PICKETT STAT RULE

A MULTI-PURPOSE SLIDE RULE
FOR GENERAL AND STATISTICAL USE

Front Side

$(p+q)^n$	Coefficients of the binomial distribution for n's from 3 to 12; ${}_nC_r$; 2^n
$X^2\ df^{.01}_{.05}$	Chi Square values (on A scale) required for significance at the .01 and .05 levels for degrees of freedom from 1 to 30.
A,B	Standard scales, half length logarithmic scales; squares and square root with C and D scales; fourth powers and roots with $\sqrt{\ }$ scale.
BI	Inverted B scale; reciprocals of values on B; cubes and cube roots with A and D scales; other power and roots; compound multiplication/division problems.
L	Full length scale of equal parts (decimal exponents of 10). Logarithms of values on C scale.
CI	Inverted C scale; reciprocals of values in C scale.
C,D	Standard Scales; full-length single logarithmic scales.
$\sqrt{\ }$	Double length logarithmic scale; squares and square roots with D scale; fourth powers and roots with A scale.

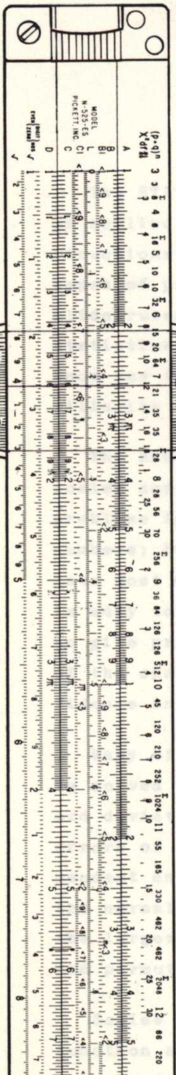
Back Side

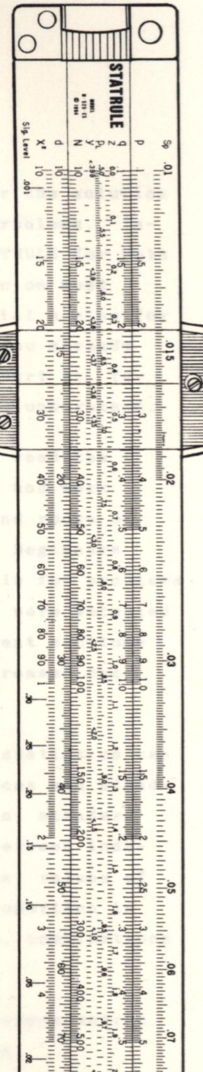
Sp	Standard error scale; used with p,q N scales.
p, pq	Proportion scale, variance of proportions.
q	Proportion scale $(1-p)$
z	Standard score (x/σ)
P_L	Proportion in the larger area
y	Ordinate of the normal curve
N	Sample size scale, $f_1 + f_2$, $a + d$; used with p,q, S_p scales and with d and X^2 scales.
d	Difference scale, $f_1 - f_2$, $a - d$
X^2	Chi Square scale, for 2 x 2 (1 df) problems
Sig. Level	Significance levels for Chi Square values (1 df).

SPECIAL INSTRUCTIONS FOR THE USE OF THESE SCALES INCLUDED WITH EACH STATRULE.

PICKETT INC., PICKETT SQUARE, P.O. Box 1515, Santa Barbara, California 93102

PICKETT STAT RULE





SLIDE RULE FOR APPLIED STATISTICS

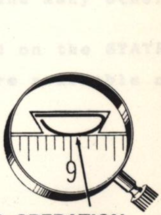
Any area of applied statistics – psychology, sociology, education, marketing research, quality control, business and engineering – whether student or professional – will be made more readily effective, and easier for the analyst with Pickett's specially developed statistical slide rule. Created by specialists in statistical analysis, it relates itself particularly to problems in this field.

TWENTY SCALES

There are twenty scales for speedy and accurate computation of the most frequently used statistics; standard deviations, variances, sampling errors of proportions, percentages, frequencies; significance tests of differences; values of the normal curve; significant Chi Square values; coefficients of the binomial distribution. In addition, this new slide rule retains the most used scales for general problem solution, found on standard rules.

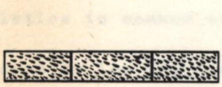
CONSIDER THESE HELPFUL FEATURES

- ▼ Scale designations in appropriate units
- ▼ Decimal points located for most problems
- ▼ BI scale for compound multiplication/division problems; cubes and cube roots
- ▼ 20" square root scales give 3 to 4 place accuracy
- ▼ Special instructions included with each Stat Rule



SMOOTH OPERATION

Eze-Slider Tension Springs automatically equalize slider-to-stator pressure throughout the full length of the slide rule.



ALL METAL ACCURACY

Metal construction of Pickett slide rules assures perfect operation and dimensional stability regardless of heat or cold, dry or damp. Wood tends to shrink, swell and distort under extremes of temperature and humidity. Most synthetic materials have limited high-temperature tolerance.

PREFACE

The STATRULE is a multi-purpose slide rule, designed for the solution of applied statistical problems and general mathematical problems. Instructions are given in this manual for the use of the STATRULE for both types of problems. The basic operations, which can be done on most slide rules, are described in Part 1. The use of the special scales for statistical problems is described in Part 2. Even though you already know how to use a slide rule, it will pay to work through Part 1: familiarity with the notation used will make Part 2 easier to understand.

The basic operations described in Part 1 include how to read the scales and locate decimal points; how to multiply, divide, and work problems in proportion; how to find reciprocals, powers, and roots of numbers; how to use the STATRULE for combined operations. Beginners have most difficulty with scale reading; how to <u>set</u> the rule for problems is easy to learn. The many example problems in the manual were selected to give practice in locating and reading numbers on different sections of the scales. Work the problems: the result will be increased confidence in your ability to use the STATRULE effectively.

Many of the problems frequently encountered in applied statistics can be solved with the special scales on the STATRULE: variances and standard deviations of proportions, percentages, and frequencies; standard errors of proportions; significance tests of differences between independent and correlated proportions, and between frequencies; values of the normal curve, the standard score, the ordinate, the proportion in the larger area; coefficients of the binomial distribution, combinations and permutations; and many other statistics in common use.

Scales not found on the STATRULE, such as Log Log and trigonometric function scales, are available on other Pickett Slide Rules.

FOREWORD

Why the STATRULE?

The STATRULE was designed by Human Factors Research, Inc., to meet a particular need not met by other slide rules: a need for a slide rule for the computation of both applied statistical problems and general mathematical problems. The more frequently used scales found on many slide rules are retained on the STATRULE for the basic operations of multiplication and division, finding powers and roots, and so on. The special scales are arranged and notated for the rapid solution of the more common problems in applied statistics.

Who is the STATRULE for?

The STATRULE is designed to be used by students, instructors, and professionals in

Business	Marketing Research
Education	Opinion Survey Research
Psychology	Human Engineering
Sociology	Quality Control Engineering

and in the many other areas that involve the use of statistics in the design and analysis of experiments and in the interpretation of data.

Students will find the STATRULE easy to learn and that its use will make statistics easier to understand and apply to "real-life" problems. The time spent in mastering the STATRULE will be more than repaid by an increased ability to handle both statistical and general problems.

Instructors will find the STATRULE to be an invaluable teaching aid. It will help to dispel some of the fear that students have about mathematics and, in particular, about statistics. The STATRULE can be used with any general statistics textbook. Its use by students will permit test questions, involving computations, that ordinarily cannot be asked in limited time periods.

Professionals will find the STATRULE to be an indispensable tool for day-to-day use: to design sampling plans, to analyze and interpret data, to evaluate statistical reports, to solve the frequent mathematical and statistical problems that arise in research, education, and business activity.

TABLE OF CONTENTS

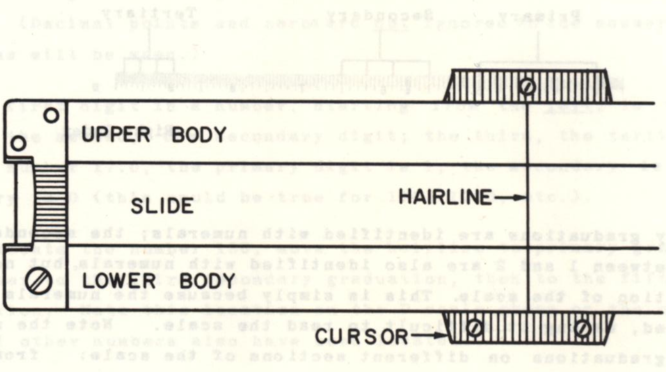
Page

PART 1 - BASIC OPERATIONS

INTRODUCTION

The slide rule is a simple mechanical device for adding and subtracting distances. Multiplications or divisions can be made on the slide rule because the distances that are added or subtracted correspond to the logarithms of numbers. The basic scales (C and D, A and B) are logarithmic scales. The relationship between some of these scales can be changed (C and D) to perform the operations of multiplication and division. The relationship between other scales is fixed (A and D); these are used to find the powers and roots of numbers.

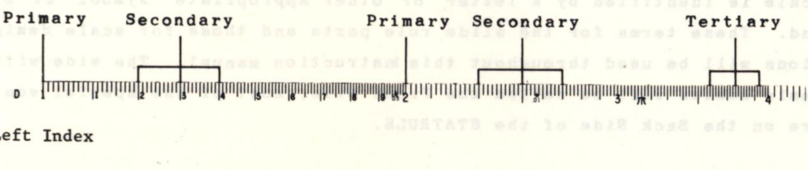
The parts of the slide rule are shown in the illustration below. Each scale is identified by a letter or other appropriate symbol at either end. These terms for the slide rule parts and those for scale designations will be used throughout this instruction manual. The side with the basic scales will be called the Front Side; most of the special scales are on the Back Side of the STATRULE.

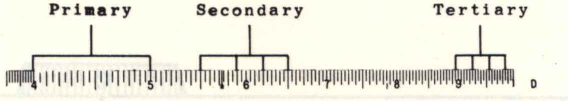


HOW TO READ THE SCALES

Most errors that occur in slide rule computations are the result of incorrect scale readings: either a number is incorrectly located on a scale or incorrectly read from the scale. Make sure you know how to read the scales before attempting any operations with them.

Three kinds of scale graduations are used: primary, secondary, and tertiary. Primary graduations are always identified with a numeral (1, 2, 3, ... 9, 1); secondary and tertiary graduations are usually not (exceptions will be noted). There are always nine secondary graduations between primary graduations, subdividing these spaces into ten parts. The number of tertiary graduations depends on the particular scale and the particular section of the scale. Consider the D scale (lower body, Front Side) shown below.





Primary graduations are identified with numerals; the secondary graduations between 1 and 2 are also identified with numerals, but not on any other section of the scale. This is simply because the numerals would be too crowded, making it difficult to read the scale. Note the number of tertiary graduations on different sections of the scale: from primary

1 (left index) to 2 there are nine tertiary graduations that further divide the spaces between secondary ones into ten parts; from 2 to 4 there are four tertiary graduations between secondaries, dividing the spaces into five parts; and from 4 to 1 (right index) only one tertiary between secondaries, dividing the spaces into two parts. The number of tertiary graduations on different sections of the scale determine which numbers can be located exactly and which can be located approximately.

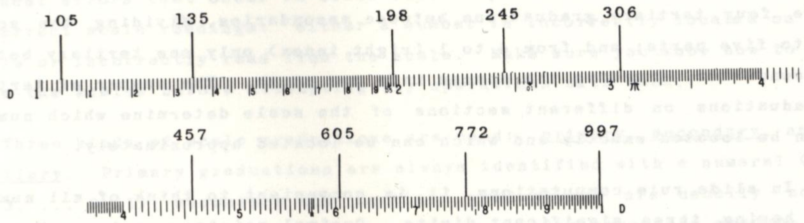
In slide rule computations, it is convenient to think of all numbers as having three significant digits. Decimal points are ignored in locating or reading numbers on the D scale. The following numbers would all be located at the same place on the scale.

135,000.0	1.35
13,500.0	0.135
1,350.0	0.0135
135.0	0.00135
13.5	0.000135

Note that zeros are also ignored in locating numbers; <u>except</u> when the zero is a significant digit itself, as in the numbers 105, 209, 306, and so on. (Decimal points and zeros are <u>not</u> ignored in the answers to problems, as will be seen.)

The first digit in a number, starting from the <u>left</u>, is the primary digit; the second, the secondary digit; the third, the tertiary digit. In the number 17.0, the primary digit is 1, the secondary is 7, and the tertiary is 0 (this would be true for 170, 1700, etc.).

To locate the number 135, move the hairline to primary graduation 1, then over to the third secondary graduation, then to the fifth tertiary graduation. Note this location on the D scale shown on the next page. Several other numbers also have been located.

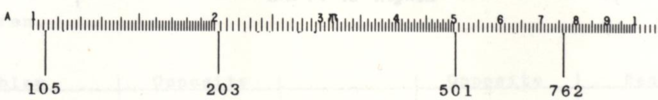


Note that any three-digit number between 100 and 200 can be located exactly on the scale between 1 and 2; four-digit numbers can be approximated. Even numbers between 200 and 400 can be located exactly; odd numbers must be approximated. Numbers ending in 0 or 5 between 400 and 1000 can be located exactly; other numbers must be approximated. The reason, of course, is the number of tertiary graduations on different sections of the scale.

Numbers that cannot be located exactly on a tertiary graduation can nonetheless be located accurately. The number 341 is located on the D scale by moving the hairline to <u>primary</u> 3, then to the fourth <u>secondary</u> graduation, then half the distance to the next <u>tertiary</u> graduation. There are four tertiary graduations between secondary ones on this section of the scale. The numbers 342, 344, 346, and 348 are located exactly on these; but 341, 343, 345, 347, 349 are located halfway between the tertiary graduations.

Locate 457 on the D scale. The numbers 455 and 460 can be located exactly; 457 must be approximated. It is located two-fifths of the distance between 455 and 460. This distance must be visually subdivided into five parts, just as the distance between 340 and 342 was subdivided into two parts to locate 341. How accurately you can locate numbers like 456, 457, 458, and 459 will depend on how accurately you visually subdivide the distances. With a little practice, this can be done very accurately indeed.

The A scale (upper body, Front Side) is graduated differently than is the D scale. This is because the A scale has two logarithmic scales in the same space as the one D scale; there simply is not space for more graduations. The primary graduations are identified with numerals; there are nine secondary graduations between the primaries; but there are fewer tertiary graduations. More numbers have to be approximated on the A scale than on the D scale. Note the location of numbers on the left half of the A scale shown below. It may seem difficult at first to locate say the number 762; but it can be done very accurately after some practice.



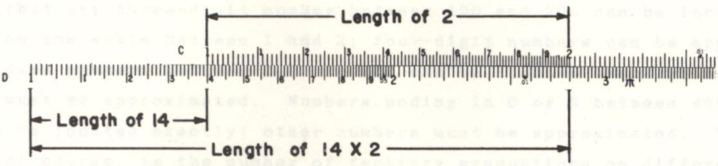
Again, most slide rule errors are scale reading errors. Practice and care in locating and reading numbers on the scales will minimize errors. Watch particularly for numbers like 105, 203, 501; these are often located as 150, 230, 510: the significant second-digit zero is overlooked.

Many of the special scales on the STATRULE have different notations for the primary graduations and different secondary graduations. But you will find them easy to read and locate numbers on, if you master the D and A scales.

MULTIPLICATION

Multiplication on the slide rule is done by adding scale distances. These distances correspond to the logarithms of the factors to be multiplied; and their sum, to the logarithm of the product. Because these are logarithmic scales the factors and products are read as numbers and not as their logarithms. The C and D scales are most frequently used for multiplication (and division). The illustration below shows these two scales set for the problem

14 x 2 = 28



The left index of the C scale is set opposite factor 14 on the D scale; opposite factor 2 on the C scale the product 28 is read on the D scale: the sum of the distances of the two factors is given on the D scale.

The general rule for multiplication is illustrated in the table below.

Problem	Opposite		Set		Opposite		Read	
g x h = p	g	D	1	C	h	C	p	D
14 x 2 = ?	14	D	1	C	2	C	28	D

This table is to be read: opposite one factor on the D scale set the index on the C scale; opposite the other factor on the C scale read the product on the D scale. Or, more generally, opposite g on D set 1 on C; opposite h on C read p on D. This notation will be used throughout the manual to illustrate the rules and problem solutions.

The hairline will ordinarily be used to locate numbers and read answers. In the simple example above the index of the C scale was used to locate 14 on the D scale, and the product on the D scale was easily located opposite the primary 2 on the C scale. Most problems require the use of the hairline.

Note that the set-up for the example problem would be the same for each of the following problems.

14 x 20 = 280
1.4 x 20 = 28.0
1.4 x 2 = 2.80
140 x 20 = 2800

The decimal point is not difficult to locate in the answers to these problems. In other problems, the decimal point can often be located by approximation.

Problem	Opposite		Set		Opposite		Read	
18.8 x 32.6 = ?	18.8	D	1	C	32.6	C	613	D

The approximate answer is 20 x 30 = 600: the decimal point then must be located so, 613.0; the answer cannot be 61.3 or 6130.

In the example problems the left index of the C scale was used. Some problems require that the right index be used:

61 x 4 = 244

If the left index on C were set opposite the factor 61 on D, the other factor 4 on C would be off the scale: the answer could not be read. Use of the right index on C permits solution of the problem.

Multiplication problems with three or more factors can be solved easily.

Problem	Opposite		Set		Opposite		Read	
24.2 x 3.3 x 51.5 = ?	24.2	D	1	C	3.3	C	x	D (Cont.)
	x	D	1	C	51.5	C	411	D

The intermediate product x can be read, but there is no interest in it. It is under the hairline and is treated as a factor in the continued solution of the problem. The decimal point in the answer is located by approximation: 20 x 3 x 50 = 3000; the answer must be 4110, not 411 or 41,100.

__Problems__

20.5 x 63.0 = 1290
9.2 x 10.6 = 97.5
36.3 x 2.5 = 90.8
0.005 x 72.0 = 0.36
173 x 51.6 = 8930

6.2 x 0.071 x 12.0 = 5.28
15.1 x 26.2 x 8.3 = 3280
0.04 x 1200 x 3.33 = 160
44.0 x 9.5 x 13.0 = 5430
63.0 x 2.1 x .012 = 1.58

DIVISION

Division on the slide rule, as in mathematics, is the inverse operation of multiplication: it is done by __subtracting__ scale distances.

Problem	Opposite		Set		Opposite		Read	
g ÷ h = q	g	D	h	C	1	C	q	D
12 ÷ 3 = ?	12	D	3	C	1	C	4	D

Opposite the dividend (12) on D set the divisor (3) on C; opposite 1 on C read the quotient (4) on D. Compare this solution with that for the first example problem in multiplication: the setting for 14 x 2 = 28 is also the setting for 28 ÷ 2 = 14.

It is helpful to remember that in a multiplication problem the answer on D is opposite one of the factors on C; in a division problem the answer on D is opposite the index on C.

Problems

236 ÷ 8.2 = 28.8	0.03 ÷ 21.0 = 0.00143
16.0 ÷ 0.5 = 32.0	710 ÷ 83.0 = 8.55
32.1 ÷ 64.2 = 0.500	2960 ÷ 0.65 = 4550
5320 ÷ 25.3 = 210	19.0 ÷ 9.6 = 1.98
9.6 ÷ 18.0 = 0.533	6.12 ÷ 43.4 = 0.141

COMBINED OPERATIONS

Many problems involve the combined operations of multiplication and division.

Problem	Opposite	Set	Opposite	Read
$\frac{16 \times 3}{8} = ?$	16 D	8 C	3 C	6 D

Note that the division 16 ÷ 8 is done first; the quotient opposite 1 on C is then multiplied by 3 on C; the answer is read under the hairline on D. The quotient could also be read, of course, but there is no interest in it.

In solving some combination problems, it is necessary to interchange the indexes on C.

Problem	Opposite	Set	Opposite	Read
$\frac{24 \times 21}{6} = ?$	24 D	6 C	21 C	84 D

The factor 21 is off the scale when the division 24 ÷ 6 is done: move the hairline to the right index on C; then move the slide so the left index on C is under the hairline; opposite 21 on C read the answer 84 on D.

Note that in a problem like the above examples, where there is one more factor in the numerator than in the denominator, the answer on D is opposite the last numerator factor on C: the problem ends with a multiplication. In a problem where there are equal numbers of factors in the numerator and denominator, the answer on D is opposite the index on C: it ends with a division. Problems of the following types will be dealt with in a later section.

$$\frac{a \times b \times c \times d}{e \times f} = ? \qquad \frac{a}{b \times c} = ?$$

Problems

$$\frac{3.5 \times 1.8}{0.05} = 126 \qquad \frac{57 \times 33}{6.0 \times 93.0} = 3.36$$

$$\frac{64.0 \times 28.0}{13.0 \times 73.0} = 1.89 \qquad \frac{0.06 \times 3.8 \times 2.1}{7.2 \times 0.01 \times 10.2} = 0.652$$

$$\frac{823 \times 1.2 \times 68.0}{5.0 \times 11.6} = 1160 \qquad \frac{11.3 \times 8.2}{0.006} = 15{,}400$$

PROPORTION

Opposite 2 on D set the left index on C. The following equal ratios also have been set.

$$\frac{1}{2} = \frac{1.5}{3} = \frac{2}{4} = \frac{2.5}{5} = \frac{3}{6} = \frac{4}{8}$$

In fact, each ratio formed by opposite values on C and D is equal to any other ratio of opposite values on the two scales. This makes it simple to solve proportion problems.

Problem	Opposite		Set		Opposite		Read	
$\frac{2}{3} = \frac{5}{x}$; x = ?	3	D	2	C	5	C	7.5	D

The problem could have been written 2 : 3 = 5 : x. Note that the numerator terms on each side of the equation are on the C scale, and the denominator terms are on the D scale. The problem can be illustrated as follows.

$$\frac{\text{C scale} \quad 2 \quad 5}{\text{D scale} \quad 3 \quad x}$$

It is easy to see that value of the unknown x can be determined by the same setting, whatever its position in the equation.

$$\frac{a}{b} = \frac{x}{c} \qquad \frac{a}{x} = \frac{b}{c} \qquad \frac{x}{a} = \frac{b}{c}$$

Multiplication and division problems can be thought of as problems in proportion.

$$14 \times 2 = x \qquad \frac{1}{14} = \frac{2}{x}$$

$$12 \div 3 = x \qquad \frac{1}{x} = \frac{3}{12}$$

Problems

$$\frac{9.2}{63.0} = \frac{x}{21.2} \quad x = 3.10 \qquad \frac{x}{76.8} = \frac{32.5}{4.7} \quad x = 531$$

$$\frac{84.2}{x} = \frac{29.3}{.051} \quad x = 0.146 \qquad \frac{136}{521} = \frac{12.0}{x} \quad x = 46.0$$

DECIMAL POINT LOCATION

We have already used the approximation method to locate the decimal point in answers: numbers are rounded to facilitate mental arithmetic.

$$16.8 \times 110 \text{ is about } 20 \times 100 = 2000$$

The answer then is 1850, not 185 or 18,500.

A combination of rounding and canceling may be used to locate decimal points in some problems.

$$\frac{34.1 \times 68.0}{146} \text{ is about } \frac{30 \times \not{7}0}{\not{1}\not{4}0_{\;2}} = 15$$

The slide rule answer is 15.9.

Often, decimal points in the problem can be relocated to simplify location in the answer.

$$1650 \times .0052 = 1.65 \times 5.2$$

The decimal point is moved three places to the left in the first factor and three places to the right in the second one: 1650 is divided by 1000, and .0052 is multiplied by 1000; which is equivalent to multiplying the equation by 1 (1000/1000) and, of course, does not change its value. The approximate answer is 2 x 5 = 10; the slide rule answer is 8.58.

Decimal point relocation also helps in more complicated problems.

$$\frac{1650 \times .0052}{.053 \times 39.6} = \frac{1650 \times 5.2}{53.0 \times 39.6}.$$

$$\text{or about } \frac{2000 \times 5}{50 \times 40} = 5$$

The numerator and denominator were each multiplied by 1000: .0052 became 5.2; .053 became 53.0. By rounding and canceling, the approximate answer is 5. The slide rule answer then is 4.09.

<u>Scientific</u> <u>notation</u> provides the most generally useful method for keeping track of the decimal point, especially in complicated problems. Any number may be expressed in scientific notation; that is, as a number from 1 to 9 times some power of 10. For example, in scientific notation, the number 135,000 would be written as 1.35×10^5. Consider the following table.

Number	Number in Scientific Notation
1,350,000.0	1.35×10^6
13,500.0	1.35×10^4
135.0	1.35×10^2
1.35	1.35×10^0
0.0135	1.35×10^{-2}
0.00135	1.35×10^{-3}
0.0000135	1.35×10^{-5}

Some numbers have been skipped in the above table: for example, $1,350 = 1.35 \times 10^3$. How would you write 0.000135 in scientific notation?

Recall the meaning of an exponent. In the expression 10^4, 4 is the exponent.

$$10^4 = 10 \times 10 \times 10 \times 10 = 10,000$$

$$\text{Thus: } 1.35 \times 10^4 = 1.35 \times 10,000$$

The meaning of a negative exponent is shown in the following expressions.

$$10^{-3} = \frac{1}{10^3} = \frac{1}{10 \times 10 \times 10}$$

$$\text{Thus: } 1.35 \times 10^{-3} = 1.35 \times \frac{1}{1000} = \frac{1.35}{1000}$$

Keep in mind that $10^0 = 1$; in fact, $n^0 = 1$, where n is any number.

To express a number in scientific notation:

a. move the decimal point to the right of the first non-zero digit (to form a number from 1 to 9);

b. the number of places the decimal point must be moved determines the exponent of 10;

c. the direction the decimal point is moved determines the sign of the exponent; positive if to the left, negative if to the right. (Simply: numbers greater than 1 have positive exponents; numbers less than 1 have negative exponents.)

Scientific notation could have been used to relocate the decimal points in the example problems above.

$$1650 \times .0052 = 1.65 \times 10^3 \times 5.2 \times 10^{-3} = 1.65 \times 5.2 = 8.58$$

The "law of exponents" was used to compute the value of the factors 10^3 and 10^{-3}. Part of the law is illustrated in the expressions below.

$$10^a \times 10^b = 10^{a+b} \qquad 10^3 \times 10^{-3} = 10^{3+(-3)} = 10^0 = 1$$

$$\frac{10^a}{10^b} = 10^{a-b}$$

A problem in multiplication or division can be solved by expressing the numbers in scientific notation, combining the powers of 10 by the law of exponents, and performing the indicated operations on the slide rule.

$$\frac{2530 \times 86.2}{31.2 \times .0031} =$$

$$\frac{2.53 \times 10^3 \times 8.62 \times 10^1}{3.12 \times 10^1 \times 3.1 \times 10^{-3}} =$$

$$\frac{2.53 \times 8.62}{3.12 \times 3.1} \times \frac{10^4}{10^{-2}} = 2.25 \times 10^6$$

Note that $\frac{10^4}{10^{-2}} = 10^{4-(-2)} = 10^6$. The number may now be written: 2,250,000.

RECIPROCALS

There are two inverted scales on the STATRULE, CI and BI, both on the slide. Note that these scales read from right to left and that they are identical to their companion scales: CI with C, and BI with B. Numbers on CI are reciprocals of numbers on C (and the reverse); and numbers on BI are reciprocals of numbers on B. Recall that the reciprocal of n is 1/n, where n is any number. Verify the following relationships between C and CI.

Problem	Opposite		Read		Decimal Answer
$\frac{1}{2} = ?$	2	C	5	CI	0.5
$\frac{1}{16} = ?$	16	C	625	CI	0.0625
$\frac{1}{342} = ?$	342	C	292	CI	0.00292
$\frac{1}{5500} = ?$	5500	C	182	CI	0.000182
$\frac{1}{.4} = ?$	.4	C	25	CI	2.5
$\frac{1}{.08} = ?$	.08	C	125	CI	12.5

The same relationships could have been read on the B and BI scales. Note the relationship between location of the decimal point in n and in the reciprocal of n.

The inverted scales can be used to simplify the solution of many problems. Consider these equivalent expressions.

$$a \times b = \frac{a}{1/b} \qquad 24 \times 6 = \frac{24}{\frac{1}{6}}$$

$$\frac{a}{b} = a \times 1/b \qquad \frac{24}{6} = 24 \times 1/6$$

Check these on the slide rule. For the multiplication: opposite 24 on D set 6 on CI; opposite 1 on C read 144 on D. For the division: opposite 24 on D set 1 on C; opposite 6 on CI read 4 on D.

When the CI and D scales are used for multiplication, the product is always opposite the C index that is on the scale. You do not have to decide whether the right or left index should be used to set up a problem. A very useful rule for slide rule operations is to use the CI and D scales for multiplication problems and C and D for division problems.

The following problems demonstrate the usefulness of the CI scale.

Problem	Opposite		Set		Opposite		Read	
$2.2 \times 4.5 \times 8.6 = ?$	2.2	D	4.5	CI	8.6	C	85.1	D
$\frac{18.6}{3.8 \times 4.75} = ?$	18.6	D	3.8	C	4.75	CI	1.04	D
$\frac{1}{5.6 \times .04} = ?$	1	D	5.6	C	.04	D	4.46	CI

To solve the first problem, it was rewritten in the form:

$$(2.2 \div 1/4.5) \times 8.6$$

The second problem was rewritten in the form:

$$\frac{18.6 \times 1/4.75}{3.8}$$

Compare the number of steps in these solutions with those of other methods you have learned.

In the solution of the third problem, the functions of the C and D scales were interchanged: the product of the denominator factors was read on C (rather than D) to permit direct reading of the reciprocal on CI, the answer to the problem. If the denominator product had been computed in the usual way (the answer on D), it would have been necessary to line up the C and D indexes to find the reciprocal--an extra operation. A good many problems can be solved in fewer steps if you take advantage of the interchangeability of the scales.

All of these problems could have been solved by using the A, B, and BI scales. A and B can be used together, just as C and D, to multiply and divide. It is often easier to solve compound problems, those with several factors in the numerator and denominator, on the A, B, and BI scales. This is because, with a little foresight, there is always a full scale (B or BI) on the slide. Indexes do not have to be interchanged, as often happens with C and D.

The BI scale on the STATRULE permits the flexibility of operation of duplex-type slide rules. Those who have used standard slide rules a great deal may miss the CF and DF scales (these scales eliminate some, but not all, of the need to interchange C indexes in solving problems). But the solution of problems where CF and DF are useful can easily be handled on A, B, and BI, without having to be concerned about "off-scale" values.

<u>Problems</u>

$$\frac{1}{105} = 0.00952 \qquad 16.2 \times 4.8 \times 8.3 = 646$$

$$\frac{1}{.007} = 143 \qquad \frac{74}{.05 \times 27.2} = 54.4$$

$$\frac{1}{38.2} = 0.0262 \qquad \frac{1}{69.5 \times 4.1} = 0.00351$$

POWERS AND ROOTS

The ease with which certain powers and roots of numbers are obtained on the slide rule alone makes it a very useful instrument. Consider the relationships between numbers on the A, D, and √ scales shown in the table below. (The √ scale is on the lower body, Front Side.)

Scale	a. Numbers		b. Numbers		c. Numbers	
A	n	16	n^4	625	n^2	81
D	$\sqrt{n}$	4	n^2	25	n	9
√	$\sqrt[4]{n}$	2	n	5	$\sqrt{n}$	3

a. Opposite 16 on A (right half) read 4 on D and 2 on √ (upper half).

b. Opposite 5 on √ (lower half) read 25 on D and 625 on A.

c. Opposite 9 on D read 81 on A and 3 on √ (upper half).

Note that the √ scale is a "double length" logarithmic scale: it bears the same relationship to D as D does to A. Because of its greater length it has many more tertiary graduations, and the secondary graduations are identified with numerals up to primary 5. Numbers can be located and read very accurately and quickly on the √ scale. For this reason, D and √ are used more frequently than A and D to find the squares and square roots of numbers.

In the examples above, numbers were sometimes read on the right or left half of the A scale or on the upper or lower half of the √ scale. The rule for which half of A or √ to use to find square roots is illustrated below.

Problem	Read on D Opposite A	Opposite D Read on √	Answer
135,000.0	Right	Lower	368
13,500.0	Left	Upper	164
135.0	Left	Upper	16.4
13.5	Right	Lower	3.68
0.135	Right	Lower	.368
0.0135	Left	Upper	.164
0.00135	Right	Lower	.0368

If n > 1, use A right or √ lower when n has an even number of digits; A left or √ upper when an odd number.

If n < 1, use A right or √ lower when n has an even number of zeros between the decimal point and the first digit; A left or √ upper when an odd number of zeros.

The decimal point can be located in the square root of n by setting n in "groups of two" in either direction from the decimal point.

$\sqrt{n}$	3 6 8	1 6 4	3. 6 8
n	13'5,0'00	1'35'00	13.'50'00
$\sqrt{n}$	0. 1 6 4	0. 0 3 6 8	
n	0.01'35'00	0.00'13'50'00	

The decimal point in n^2 is easily located by the use of scientific notation and the law of exponents.

$$(1200)^2 = (1.2 \times 10^3)^2 = (1.2)^2 \times (10^3)^2 = 1.44 \times 10^6 = 1,440,000$$

The power relationships between the A, D, and √ scales can be used to solve problems that involve squares or square roots of numbers.

Problem		Opposite		Set		Opposite		Read	
$\sqrt{\frac{4 \times 6}{35}}$	= ?	4	D	35	C	6	C	.828	√
$\frac{12}{\sqrt{3}}$	= ?	12	D	3	A	1	C	6.93	D
$\frac{\sqrt{27}}{4.2}$	= ?	27	A	4.2	C	1	C	1.24	D
$\frac{(13)^2}{(6.2)^2}$	= ?	13	D	6.2	C	1	B	4.40	A
$\frac{(28.2)^2}{7.4}$	= ?	28.2	√	7.4	C	1	C	107	D
$(16.3)^2 \times \sqrt{5.35}$	= ?	16.2	√	1	C	5.35	B	615	D
$\frac{1}{\sqrt{67}}$		67	B					.122	CI

Study these problems carefully. Watch particularly for which half of A or $\sqrt{}$ is used in setting the problems or in reading answers. There are many such problems in statistics that can be easily solved on the STATRULE.

Note that B and C, and BI and CI, bear the same relationship to each other as do A and D. The reciprocal of the square root of n can be read directly, as was done in the last example problem above. BI and C could have been used for the same problem.

Cubes and cube roots of numbers can easily be found on the STATRULE, even though it does not have a K scale (three scales in the length of D). To find n^3, first rewrite it (or think of it) as $n^2 \times n$. Then opposite n on D set n on BI; opposite 1 on B read n^3 on A.

Problem	Opposite		Set		Opposite		Read	
$(4.7)^3 = ?$	4.7	D	4.7	BI	I	B	102	A

What you have done is solve a problem of this type:

$$(4.7)^2 \div 1/4.7$$

The inverse operation is used to find $\sqrt[3]{n}$: opposite n on A set 1 on B; then move the hairline until the same number is under it on both BI and D. This is easy to do. For example, find the cube root of 180. We know the answer is between 5 and 6 ($5^3 = 125$; $6^3 = 216$). Opposite 180 on A (left) set 1 (left) on B; the number under the hairline on BI and D is 5.65. Think out yourself why this particular setting was used. What would be the setting for the cube root of 18, of 1800? The answers are 2.6 and 12.2.

Problems

$\sqrt{\frac{6.7 \times 4.3}{12.9}} = 1.49$ $\sqrt{4960} = 70.4$

$\frac{\sqrt{58.1}}{21.2} = 0.359$ $\sqrt[3]{51.8} = 3.73$

$\frac{85.4}{(3.2)^2} = 0.119$ $(218)^3 = 10,400,000$

$\frac{1}{(12.5)^2} = 0.00641$ $\frac{1}{\sqrt{93.5}} = 0.103$

LOGARITHMS

The L scale on the slide, Front Side, is used with the C scale to find the logarithms to the base 10 of numbers. A logarithm has two parts: a mantissa, which denotes a particular series of digits; and a characteristic, which locates the decimal point in the series. The mantissa of the logarithm of a number is read on L opposite the number on C. The characteristic is determined by the value of the number. Consider the following problems.

Problem		Opposite		Read		Logarithm or Number
log 121	=	121	C	.083	L	2.083
log 32.4	=	32.4	C	.511	L	1.511
log 8500	=	8500	C	.929	L	3.929
log .423	=	.423	C	.626	L	.626 - 1
log .007	=	.007	C	.845	L	.845 - 3
log x = 4.444; x = ?		.444	L	278	C	27,800
log x = 1.398; x = ?		.398	L	250	C	25.0

Note the decimal point before the primary numbers on the L scale: these locate the decimal in the logarithm of the number. The mantissa of each of the following numbers is the same (.083): 121, 12.1, 1.21, 1210, .0121. The characteristic identifies which number the logarithm refers to. The logarithm 2.083 refers to 121; the characteristic is 2, and the mantissa is .083.

Observe the relationship between the <u>characteristic</u> of the logarithm of a number of the <u>exponent</u> of the factor 10 of the number written in scientific notation. They are identical. In fact, the exponent of 10 is the logarithm of 10 to the base 10: $\log 10^3 = 3.000$; $\log 10^1 = 1.000$; $\log 10^0 = 0$. The value of the characteristic of a number then is found by thinking of the number as if written in scientific notation.

In the last two example problems above, the characteristic of the logarithm located the decimal point in the number. Again, scientific notation was used: think of the number 278 read on C as $2.78 \times 10^4 = 27{,}800$; and $\log x = 1.398$, $x = 2.50 \times 10^1 = 25.0$.

The characteristics of the logarithms of decimal fractions may be written as in the above examples: $\log .423 = .626 - 1$; $\log .007 = .845 - 3$. It is more common to write them in this form: $\log .423 = 9.626 - 10$; $\log .007 = 7.845 - 10$. The two forms are equivalent, but the latter one is more convenient to work with.

The L scale makes it possible to raise numbers to fractional powers. For example, what is the value of $8^{1.2}$?

$x = 8^{1.2}$ $\qquad \log x = \log 8^{1.2} = 1.2 \log 8 = 1.2\ (0.902)$

$\log x = 1.082$ $\qquad x = 12.1$

This is what was done: the equation was rewritten in logarithmic form (the exponent of 8 was made a factor of log 8); the mantissa of 8 (.902) was located on L; the product of 1.2 x .902 was computed on C and D; the mantissa of log x was located on L, and x read opposite it on C.

Problems

log 182 = 2.260	log x = 9.291 - 10; x = .195
log 38.4 = 1.584	log x = 0.624 ; x = 4.21
log 9.53 = 0.979	log x = 5.110 ; x = 129,000
log .058 = 8.764 - 10	$48^{2.3}$ = 7,410

PART 2 - SPECIAL SCALES FOR STATISTICAL PROBLEMS

S_p, p, q, AND N SCALES

The S_p, p, q, and N scales are used to solve problems involving proportions, percentages, and frequencies. They are designed to simplify the computation of variances, standard deviations, standard errors, and other frequently used statistics.

Note that these scales are like ones you are already familiar with: S_p is a D scale; p, q, and N are A scales. The graduations are identical on the respective scales; and they are read in the same way. The notation on the special scales is different. Decimal points are located in the primary numerals so that numbers can be quickly read in appropriate values: the need for decimal point location is greatly reduced.

Standard errors of proportions and standard errors of the differences between proportions are read on S_p. The values indicated by the primary numerals range from .01 to .10; other values can be read on S_p, but that is the range of most of the standard errors in applied statistical problems.

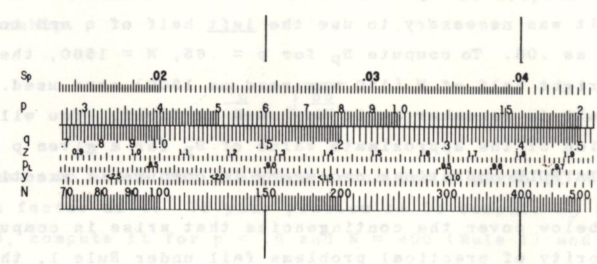
Proportions are read on p and q: $p = f/N$, where f is the frequency of a particular event, or kind of observation, and N is the total number of observations; $q = 1 - p$. Values on p and q range from 0.1 to 1.0. The actual range of such values, of course, is from 0 to 1.0; values between 0 and 0.1 can be read on the scales, as will be seen. The right half of the p scale is designated as pq, because the product p x q is read on that half. Note that .25 on pq is coded in red: this is a reminder that the maximum value possible for p x q is .25.

The total number of observations is read on N. The designated range of values is from 10 to 1000; other values can be read, but these are the most frequently used. When using the N scale, keep in mind that only integral values are read; there are no fractional observations. Thus the tertiary graduations between 10 and 50 are not ordinarily used, but they may be for N's greater than 1000: that is, 10 would be read as 1000 and 50 as 5000.

The standard error of a proportion is given by the formula

$$S_p = \sqrt{\frac{pq}{N}}$$

Compute S_p for p = .6 and N = 150: opposite .6 on p set 150 on N; opposite .4 (1 - p) on q read .04 on S_p. This is the standard error of both .6 and .4 for N = 150. The scale settings for this problem are shown in the illustration below.



This problem obviously could have been solved on the Front Side basic scales, but the arrangement and notation of the special scales provides an easier, faster, and probably more accurate solution.

Try the following problems. Watch out for the last two; if you cannot work them, refer to the rules below.

Problem		Opposite		Set		Opposite		Read	
p	N								
.73	126	.73	p	126	N	.27	q	.040	S_p
.54	82	.54	p	82	N	.46	q	.055	S_p
.65	660	.65	p	660	N	.35	q	.019	S_p
.50	40	.50	p	40	N	.50	q	.079	S_p
.83	325	.83	p	325	N	.17	q	.021	S_p
.92	65	.92	p	65	N	.08	q	.034	S_p
.65	1500	.65	p	1500	N	.35	q	.012	S_p

Note that all standard errors have been rounded to three places: this is sufficiently accurate for <u>all</u> practical problems.

In the problems above, except the last two, the right half of q was used and N was read directly from the scale notations. To compute S_p for p = .92, it was necessary to use the <u>left</u> half of q and to read the .8 graduation as .08. To compute S_p for p = .65, N = 1500, the left half of q and the right half of N (150 was read as 1500) were used. This is not as difficult to remember as it may seem at first. You will quickly develop a notion of the approximate value of S_p for a given p and N, and perform the STATRULE operations necessary to compute it exactly.

The rules below cover the contingencies that arise in computing S_p. The great majority of practical problems fall under Rule 1, the one we have used most in the example problems.

To compute S_p:

<u>Rule 1</u>. For p between .10 and .90, and N between 100 pq and 999, use the <u>right</u> q scale. The value of 100 pq for some representative p's is shown below (also see Rule 5).

q	.5	.6	.7	.8	.9
100 pq	25	24	21	16	10

Rule 2. For p less than .10 and greater than .90, and N between 100 pq and 999, use left q scale.

Rule 3. For p between .10 and .90, and N greater than 1000, use left q scale and right N scale (read 100 as 1000, etc.). For N greater than 10,000, another rule is needed. But forget it: for all practical purposes, S_p is negligible with that large an N.

Rule 4. For p less than .10 and greater than .90, and N greater than 1000, use right q scale and right N scale and move the decimal point in S_p one place to the left (.07 becomes .007).

Rule 5. For N less than 100 pq, use left q scale and right N scale (read 100 as 10, etc.) and move the decimal point in S_p one place to the right (.012 becomes .12). Ordinarily you would not compute p on such small bases. If you do, S_p is so large it is virtually meaningless. Remember that if N is less than 100 pq, S_p is greater than .10.

If you have trouble with these rules, it will be helpful to remember this relationship.

$$\frac{S_p}{2} = \sqrt{\frac{pq}{4N}}$$

This means: to halve the standard error for a given p, N must be increased by a factor of 4. If your problem is to compute S_p for p = .6 and N = 1600, compute it for p = .6 and N = 400 (Rule 1) and halve the result.

p	.6	.6
N	400	1600
S_p	.024	.024/2 = .012

The direct way: opposite .6 on p set 160 (for 1600) on N; opposite .4 on q (left) read .012 on S_p.

The variance of p is p x q. For p = .6: opposite .6 on p set 1 on q; opposite .4 on q read .24 on pq. If p = .9 or more (.1 or less), use <u>right</u> index of q and read answer <u>left</u> p <u>and</u> move decimal one place to the left (.9 becomes .09).

The standard deviation of p is $\sqrt{p \times q}$: opposite .24 on pq read .49 on S_p (move the decimal point one place to the right).

The standard error of a percentage is 100 x S_p; of a frequency N x S_p. The computation is obvious.

A test of the significance of the difference between independent proportions is given by the formula below, where t is as defined: the ratio of the difference and the standard error of the difference.

$$t = \frac{p_1 - p_2}{\sqrt{S_{p_1}^2 + S_{p_2}^2}}$$

Some non-slide-rule operations are required to solve t: the indicated subtraction and addition. Assume the following values:

$p_1 = .65$ $\quad$ $p_2 = .48$

$N_1 = 80$ $\quad$ $N_2 = 70$

Is $p_1 - p_2 = .65 - .17$ a significant difference?

Problem	Opposite		Set		Opposite		Read	
$S_{p_1}^2 = ?$	.65	p	80	N	.35	q	284	pq
$S_{p_2}^2 = ?$	.48	p	70	N	.52	q	356	pq

Note that we solved for S_p^2 and that it is read on the pq scale. We can ignore the decimal points in summing the two S_p^2 values; the STAT-RULE will keep track for us.

$$S_{p_1}^2 + S_{p_2}^2 = 284 + 356 = 640$$

$$(\text{actually: } .00284 + .00356 = .00640)$$

Locate the sum 640 (.640) on pq. Opposite .640 on pq read .08 on S_p: this is the standard error of the difference between p_1 and p_2.

Do not move the hairline. Turn the rule to the Front Side. The number 8 is under the hairline on D. Opposite 8 on D set 17 on C (.17 = $p_1 - p_2$); opposite 1 on D read 2.13 on C. This is the value of t.

Note the .05 notation in red at 1.96 on C: this is the value of t required for significance at the .05 level. The .01 notation in red at 2.57 on C is the value of t at the .01 level.

A t of 2.13 is significant beyond the .05 level: the difference between p_1 and p_2 would have occurred by chance less than 5 out of a 100 times. We will take the risk and conclude that p_1 and p_2 are different.

A caution: if S_p is less than .0316, S_p^2 is obviously read on the left half of p, and the decimal point is moved one place to the left. Assume the following values:

$$p_1 = .15 \qquad p_2 = .26$$
$$N_1 = 150 \qquad N_2 = 125$$

Then

$$S_{p_1}^2 = 085 \text{ on p (actually .00085)}$$

$$S_{p_2}^2 = 154 \text{ on pq (actually .00154)}$$

$$S_{p_1}^2 + S_{p_2}^2 = 239 \qquad \text{(actually .00239)}$$

$$S_{p_1 - p_2} = .049$$

Verify that t = 2.25, and make the appropriate conclusion about the difference.

When N_1 and N_2 differ greatly in size, a single weighted estimate of the population variance should be used to evaluate the difference between p_1 and p_2 (many statisticians recommend a weighted estimate always be used). To compute a weighted average, $\overline{p}$, of p_1 and p_2

$$\overline{p} = \frac{N_1 p_1 + N_2 p_2}{N_1 + N_2} \qquad \overline{q} = 1 - \overline{p}$$

$$\overline{p}\,\overline{q} = \text{weighted variance}$$

$$S_{p_1 - p_2} = \sqrt{\frac{\overline{p}\,\overline{q}}{N_1} + \frac{\overline{p}\,\overline{q}}{N_2}}$$

Problems

Compute pq, $\sqrt{pq}$, S_p for these problems:

p	N	pq	$\sqrt{pq}$	S_p
.63	88	.233	.483	.051
.34	505	.234	.474	.021
.78	185	.174	.414	.030
.16	62	.134	.367	.047
.52	3200	.250	.500	.003
.94	315	.056	.238	.013

Compute a t-test for these, using unweighted and weighted population variances.

$p_1 = .18$ $\quad p_2 = .25$ $\qquad\qquad p_1 = .54$ $\quad p_2 = .61$

$N_1 = 228$ $\quad N_2 = 167$ $\qquad\qquad N_1 = 2600$ $\quad N_2 = 312$

t = $\qquad\qquad\qquad\qquad$ t =

THE d AND X^2 SCALES

The d and X^2 (Chi Square) scales, with N, are used for significance tests of differences between frequencies and differences between correlated proportions.

Both d and X^2 are graduated in appropriate units: decimal points are located. The range of d is from 10 to 100; values outside this range can be read. The range of X^2, starting and ending on the middle index, is from 1 to 100, which covers all practical problems. Tertiary graduations on the d scale are not used within the range notated: differences are integral values. They <u>are</u> used for d greater than 100.

The significance levels for representative values of X^2 for one degree of freedom are indicated in red below the scale (notated: Sig. Level). In a test of significance, there is ordinarily no interest in the actual value of X^2, but there is in the significance level it represents. This can be read directly on the STATRULE.

A Chi Square test of the significance of the difference between two frequencies when the hypothesis is a 50-50 split is given by the formula

$$X^2 = \frac{(f_1 - f_2)^2}{f_1 + f_2}$$

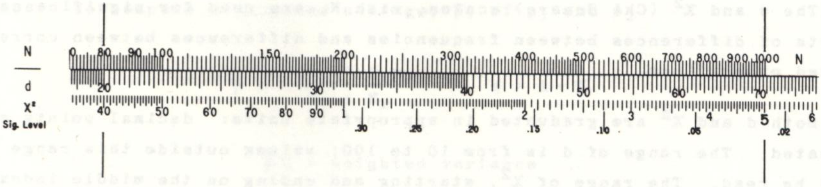
f_1 = one frequency

f_2 = the other frequency

$f_1 - f_2$ = d, the difference between them

$f_1 + f_2$ = N, the total number of observations

Assume N = 80, f_1 = 50, f_2 = 30: Is f_1 significantly different than f_2? Opposite 20 (50-30) on D set 80 on N; opposite 1000 (right index) read 5.00 on X^2. This value of X^2 is significant beyond the .05 level. We conclude the frequencies are different. The STATRULE setting for this problem is shown on the next page.



Consider the following problems; in each, test for the significance of the difference between the frequencies.

Problem			Opposite		Set		Opposite		Read
f_1	f_2	N							Sig. Level
60	40	100	20	d	100	N	1000	N	$< .05$
173	127	300	46	d	300	N	1000	N	$< .01$
8	2	10	60	d	10	N	10	N	$> .05$
900	700	1600	20	d	16	N	10	N	$< .001$
16	9	25	70	d	25	N	10	N	$> .15$

The first two problems were solved using the scale notations as given. In the third problem, 6 was read as 60 on d and the left index (10) located X^2. In the fourth, 200 was read as 20 on d, 1600 as 16 on N, and the left index (10) located X^2. The fifth problem was like the second.

The rules:

Rule 1. For N between 10 and 1000 and d between 10 and 100, read scales as notated and use right index (1000) of N.

Rule 2. For N between 10 and 26 and d less than 10, read d as 1 to 10, and use left index (10) of N. For N's greater than 26, d's less than 10 are not significant (less than .05).

Rule 3. For N greater than 1000 and d greater than 100, read d as 100 to 1000 and N as 1000 to 10,000, and use either right or left index of N (whichever is "on-scale"). For N's greater than 1000, d's less than 100 are not significant.

It is easy to determine what d is required for significance for a given N at a given significance level. For example, what difference is required for significance at the .05 level for an N of 200? Opposite the .05 sig. level set 1000 on N; opposite 200 on N read 28 on d (always round up). In fact, note you can read the significant d's for any N between 26 and 1000 with the same setting. The value of f_1 is given by the simple formula

$$f_1 = \frac{N + d}{2} = \frac{200 + 28}{2} = 114$$

Use the formula below to determine the N required to detect a given frequency split at a given significance level.

$$N = \frac{X^2}{(p_1 - p_2)^2}$$

Assume X^2 at the .05 level, $p_1 = .55$ and $p_2 = .45$.

$$N = \frac{3.84}{(.55 - .45)^2} = \frac{3.84}{(.01)^2} = 384$$

An N of 384 will detect a frequency split of .55 - .45 at the .05 level of significance. The value f_1, of course, is .55 x 384 = 212 (round up); d = 40.

Consider a problem in which two estimates of p have been obtained from the same sample of people. Suppose, for example, that the same 100 people express their preference for Candidate A versus Candidate B before a political campaign began and <u>after</u> it had been in progress for some time. Before the campaign 55% preferred A; after some time 66% preferred A; is this a significant change in preference? Look at the contingency table below:

		After		
		Prefer B	Prefer A	
Before	Prefer A	(a) 5	(b) 50	55
	Prefer B	(c) 29	(d) 16	45
		34	66	100

A test of the significance of the difference between the correlated proportions 55/100 = .55 = p_1 and 66/100 = .66 = p_2 is given by this formula:

$$X^2 = \frac{(a-d)^2}{a+d} = \frac{(5-16)^2}{21} = \frac{(-11)^2}{21} = ?$$

This is a familiar problem you already know how to solve on the STAT-RULE: opposite 11 on d set 21 on N; opposite 1000 on N read 5.75 on X^2. The sig. level is less than .02: we conclude there is a significant gain in preference for A.

Note that the cell frequencies that are compared are the "discrepant" cell frequencies: those who preferred A before and B after versus those who preferred B before and A after.

Compute the significance of the difference between p_1 and p_2 <u>without</u> the correlation taken into account; that is, by treating them as independent proportions. Verify that the significance of the difference is less than .10. We would conclude that .66 and .55 were <u>not</u> different. Obviously, we would be making an erroneous judgment if we did not consider the correlation between the two sets of observations.

Problems

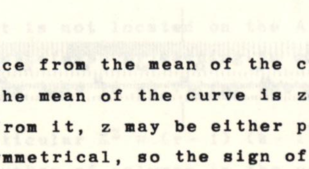
What is the significance level for these problems?

f_1	N	Sig. Level
24	36	<.02
55	95	>.10
164	240	<.001
382	695	<.01
593	1060	<.001
1950	3810	>.10

What is the size of N required to detect a 52% - 48% split at the .01 level of significance? (4150)

THE z, p_L, AND y SCALES

The z, p_L, and y scales are used to read values of the normal curve.



z is the distance from the mean of the curve to a given point on the abscissa. Since the mean of the curve is zero and z may be measured in either direction from it, z may be either positive or negative. The normal curve is symmetrical, so the sign of z is ignored in reading the scales. z may be called a <u>standard score</u> and is defined thus:

$$z = \frac{X - M}{\sigma} = \frac{x}{\sigma}$$

X = a given score in a distribution

M = the mean of the distribution

x = the deviation of the score from the mean

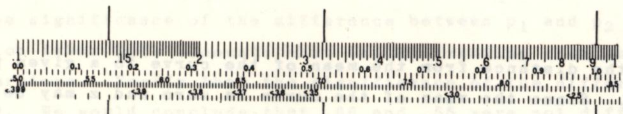
σ = the standard deviation of the distribution.

The range of z <u>on the scale</u> is from 0 to 3.0 (-3 to +3), a practical range for z. The tails of the normal curve are asymptotic, so the actual range of z is quite large.

y is the value of the ordinate of the curve at a given point on the abscissa, at a given z. The y scale, notated in red, reads from right to left: the <u>scale</u> range is from less than .005 to .399, the value of the ordinate at the mean.

p_L is the area in the <u>larger</u> portion of the curve: to the left of y if z is positive; to the right of y if z is negative. The area in the smaller portion is equal to $1 - p_L$. The area under the curve from the mean to the ordinate indicated by a given z is equal to $p_L - .50$.

The scales give the corresponding values of z, p_L, and y directly; no computation is necessary. Opposite a standard score on z read the proportion of the larger area on p_L and the value of the ordinate. Note the settings in the illustration below.



The values under the hairline are, respectively,

z	0.155	0.530	1.000
p_L	.562	.702	.841
y	.394	.346	.242

Values can be read to three-place accuracy anywhere on the scales. The decimal point is located for each value; it is read in appropriate units. Note that the graduations and primary designations differ on different sections of the scales. On the z scale, for example, the graduations change at 2.0: the number located on the first secondary graduation after 2.0 is 2.10 not 2.01 (this value would be located midway between 2.0 and the first tertiary graduation). With a little care, you'll have no trouble reading the scales.

The z, p_L, and y scales are not "working" scales: they can't be used with other scales for operations such as multiplication and division. But they do make a good deal of very useful information readily available for the solution of the many statistical problems involving normal distribution inferences.

THE X^2df SCALE

The X^2df scale is used, with A, to find the Chi Square values required for significance at the .05 and the .01 level for degrees of freedom from 1 to 30. The .05 values are coded in black; the .01 in red. Many of the degrees of freedom are identified with a numeral; those that are not are to be read as successive integers. Note that the .05 and .01 scales overlap: 1 df for the .05 is between the 18 and 25 df for .01.

The decimal point is not located on the A scale, of course. But it is easy to locate, nonetheless, by keeping in mind that the range of X^2 for the .05 level is from 3.84 to 43.7; for the .01 level, from 6.64 to 50.9.

The df for a particular $X^2 = (r-1)(k-1)$, where r is the number of rows and k is the number of columns in the contingency table.

A convenient formula for X^2 for STATRULE solution is given below.

$$X^2 = N\left[\left(\sum \frac{f_o^2}{f_r\ f_k}\right) - 1\right]$$

f_o = frequency in a cell
f_r = frequency in the corresponding row
f_k = frequency in the corresponding column
N = total number of observations

Rewrite $\frac{f_o^2}{f_r\ f_k}$ as $\frac{f_o^2 \times 1/f_k}{f_r}$ for easier solution. Remember that $\frac{f_o^2}{f_r\ f_k}$ is always less than 1 and that the sum is always greater than 1.

THE $(p+q)^n$ SCALE

$(p+q)^n$ is not actually a scale, of course, but the tabled values for the coefficients of the binomial distribution for n's from 3 to 12. Keep in mind the following rules to read $(p+q)^n$.

1. The coefficient of the first term in the expansion is always 1; the second, always n.
2. The number of terms in the expansion is n + 1.
3. The expansion is symmetrical: when n is even, there is one middle coefficient; when n is odd, two identical middle coefficients.

The value identified with the sum sign is the sum of the coefficients for a particular n. It is also equal to 2^n.

Combinations of n things taken r at a time are also given by the coefficients. Consider the expansion of $(p+q)^7$, using the above rules. Note the obvious rule for the exponents of p and q.

r		
0	1	p^7
1	7	$p^6 q^1$
2	21	$p^5 q^2$
3	35	$p^4 q^3$
4	35	$p^3 q^4$
5	21	$p^2 q^5$
6	7	$p^1 q^6$
7	1	q^7
Sum	128	

How many different ways can 3 things be taken from 7 things? The answer is 35. Permutations can be computed by multiplying the number of combinations by 3! (3 factorial = 1 x 2 x 3).

If 7 coins are tossed, what is the probability that 5 or more heads will come up? p = .5 so

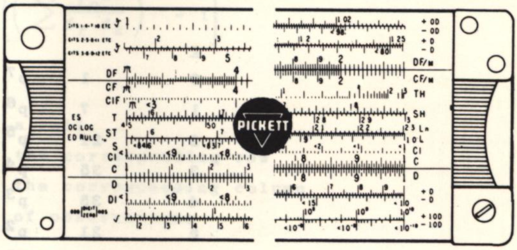
$$\frac{21 + 7 + 1}{128} = \frac{29}{128} = .226$$

The exponents of p identified the events.

OTHER PICKETT GUARANTEED ALL-METAL SLIDE RULES
For Engineers, Scientists, Businessmen and Students

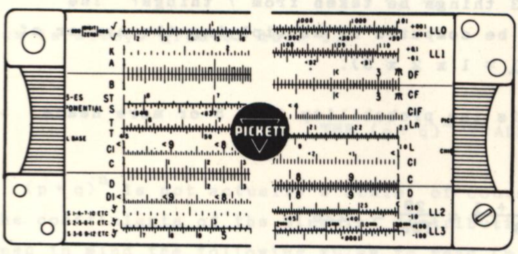
Pickett slide rules are available at every leading school stationery supply and engineering supply outlet. A few of the more popular models are listed below:

Vector Log Log Exponential Rule
10" Scale Sections, 2" Body



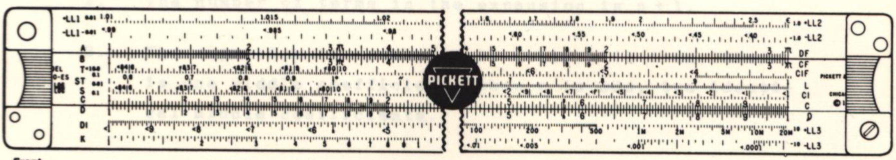
Model N4—Vector Log Log Exponential Speed Rule—For Engineers and Scientists requiring hyperbolic functions—34 scale sections including C, D, and CI on both sides, TT, ST, S, Th and Sh all on the slide, and 80-inch log log DF/M, L and Ln all on one side.

Powerlog Log Log Exponential Rule
10" Scale Section, 2" body



Model N3—Powerlog Exponential Speed Rule—For Engineers and Scientists not requiring hyperbolic functions—32 scale sections with C, D, DI on both sides, TT, ST, S, all on the slide. 80-inch log log scales and L and Ln all on one side.

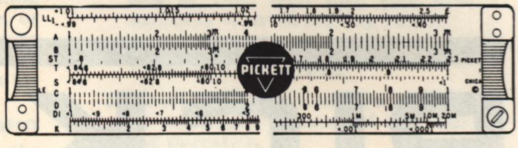
Hi-Log Rule
10" Scale Sections, 1½" Body



Model N500—Hi-Log Speed Rule—For High School Pre-Engineering Majors and Technical Students — 22 scale sections, D, and D on both sides and CF-CIF, all trig scales are on the slide. 60-inch log log scales.

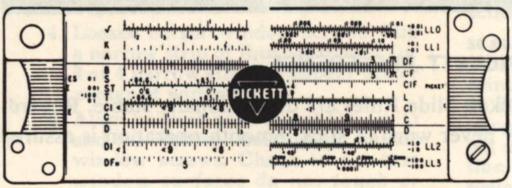
Model N600—Pocket Size Log Log Exponential Speed Rule—For Engineers and Scientists—A complete Log Log Rule in convenient pocket size, with 22 scales, including 30-inch log log, C-D on both sides, plus CI and DI with all trig scales on the slide.

Pocket Size Log Log Exponential Rule
5" Scale Sections, 1" Body



Front — Back

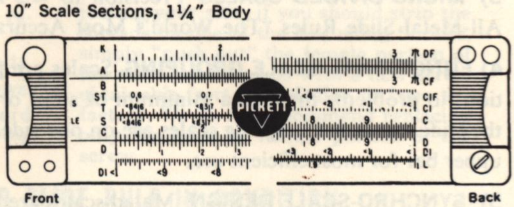
Dual Base Log Log Rule
10" Scale Sections, 1½" Body



Front — Back

Model N803—Dual Base Log Log Speed Rule—For Engineers and Scientists—28 scale sections, C, D, CI are on both sides, all trig scales are on the slide. 80-inch log log scales all on one side.

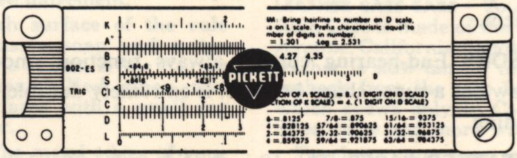
Professional Trig Rule
10" Scale Sections, 1¼" Body



Front — Back

Model N1010—Standard Trig Rule—For Students and Businessmen not requiring log log scales—17 scale sections with C, D, and DI on both sides, plus CI, all trig scales are on the slide.

Professional Quality Trainer Rule
10" Scale Section, 1¼" Body



Front — Back

Model N902—Simplex Trig Rule—For Students not requiring log log scales; has 9 basic scales for simplified operation. Instructions on the back for multiplication, division,- finding logarithms and solving trig problems.

PICKETT

ALL-METAL SLIDE RULES

THESE ARE THE REASONS FOR PICKETT PREFERENCE

1) ALL-METAL CONSTRUCTION Pickett Slide Rules are dimensionally stable. Regardless of heat or cold, dry or damp, they never warp or stick. Smooth operation is assured in all climatic conditions.

2) EYE-SAVER "5600" YELLOW COLOR The exclusive Pickett yellow-green finish makes it easy to read scales, even in bright sunlight. Eye-fatigue is sharply reduced and visual accuracy improves. White finish is also available on most models.

3) MICRO-DIVIDED SCALES Precision to ± 2 microns (.000157 inch) makes Pickett All-Metal Slide Rules "The World's Most Accurate."

4) FUNCTIONAL SCALE GROUPING Scales are positioned so as to provide quick solutions to problems through a minimum of steps or operations. Trig scales are always on the slide; extended Log Log scales are on one side; extended root scales $\sqrt{}$ and $\sqrt[3]{}$ are on upper bar for most efficient use.

5) SYNCHRO-SCALE DESIGN Mated scales are "back-to-back" so the eyes more easily focus on the correct scale. This convenient arrangement aids quick reference and easy reading.

6) EZE-SLIDER TENSION SPRINGS Spring tension is maintained at both ends to assure smooth operation in any climate throughout the length of the slide rule, with minimum adjustment.

7) NYLON CURSORS End-bearing cursors always function smoothly. The special Tyril plastic window has a super-sharp hairline, is extremely durable and provides clear, distortion-free reading.

8) TOP GRAIN LEATHER CASES The 10-inch slide rule cases have a formed plastic protective liner; the 6-inch slide rule cases have a leather jacketed spring steel pocket clip and E-Z-Out pull tab. All of these are Pickett innovations that enhance the value of treated, select leathers.

HOW TO ADJUST YOUR SLIDE RULE

Each rule is accurately adjusted before it leaves the factory. However, handling during shipment, dropping the rule, or a series of jars may loosen the adjusting screws and throw the scales out of alignment. Follow these simple directions for slide rule adjustment.

CURSOR WINDOW HAIRLINE ADJUSTMENT

Line up the hairline on one side of the rule at a time.

1. Lay rule on flat surface and loosen adjusting screws in end plates.
2. Line up C index with D index. Then align DF (or A) index with CF (or B) index.
3. Tighten screws in end plates.
4. Loosen cursor window screws. Slip a narrow strip of thin cardboard (or 3 or 4 narrow strips of paper) under center of window.
5. Align hairline with D and DF (or D and A) indices, and tighten cursor window screws. Check to see that *window surfaces do not touch or rub against rule surfaces.*

Note: The narrow strip of cardboard under the window will prevent possible distortion or "bowing in" of the window when screws are tightened. "Bowing in" may cause rubbing of window against rule surface with resultant wear or scratches.

Line up hairline on reverse side of rule.

1. Loosen all 4 cursor window screws.
2. Place narrow strip of thin cardboard under window to prevent "Bowing in" when screws are tightened.
3. Align hairline and indices on first side of rule, then turn rule over carefully to avoid moving cursor.
4. Align hairline with indices and tighten cursor screws.
5. Check to see that window surfaces do not touch surfaces of rule during operation.

SLIDER TENSION ADJUSTMENT • Loosen adjustment screws on end brackets; regulate tension of slider, tighten the screws using care not to misalign the scales. The adjustment needed may be a fraction of a thousandth of an inch, and several tries may be necessary to get perfect slider action.

SCALE LINE-UP ADJUSTMENTS • (1) Move slider until indices of C and D scales coincide. (2) Move cursor to one end. (3) Place rule on flat surface with face uppermost. (4) Loosen end plate adjusting screw slightly. (5) Adjust upper portion of rule until graduations on DF scale coincide with corresponding graduations on CF scale. (6) Tighten screws in end plates.

REPLACEABLE ADJUSTING SCREWS • All Pickett All-Metal rules are equipped with Telescopic Adjusting Screws. In adjusting your rule, if you should strip the threads on one of the Adjusting Screws, simply "push out" the female portion of the screw and replace with a new screw obtainable from your dealer, or from the factory. We do not recommend replacing only the male or female portion of the screw.

HOW TO KEEP YOUR SLIDE RULE IN CONDITION

OPERATION • Always hold your rule between thumb and forefinger at the ENDS of the rule. This will insure free, smooth movement of the slider. Holding your rule at the center tends to bind the slider and hinder its free movement.

CLEANING • Wash surface of the rule with a non-abrasive soap and water when cleaning the scales. If the Cursor Window becomes dulled clean and brighten the surfaces with a small rag and tooth powder.

LUBRICATION • The metal edges of your slide rule will require lubrication from time to time. To lubricate, put a *little* white petroleum jelly (White Vaseline) on the edges and move the slider back and forth several times. Wipe off any excess lubricant. *Do not use ordinary oil as it may eventually discolor rule surfaces.*

LEATHER CASE CARE • Your Leather Slide Rule Case is made of the finest top-grain, genuine California Saddle Leather. This leather is slow-tanned using the natural tanbark from the rare Lithocarpus Oak which grows only in California. It polishes more and more with use and age.

To clean your case and to keep the leather pliable and in perfect condition, rub in a good harness soap such as Propert's Harness Soap.

PICKETT, INC.

CHICAGO 5 • SANTA BARBARA, CALIF.

PICKETT

HUMAN
FACTORS
RESEARCH
INCORPORATED