A Seminar On
How To Use The Slide Rule

"Dad says that anyone who can't use a slide rule is a cultural illiterate and should not be allowed to vote.
Mine is a beauty - a K&E 20-inch Log-log Duplex Decitrig"
*Have Space Suit - Will Travel, 1958*. by Robert A. Heinlein (1907-1988)

Written by Mike Konshak, with acknowledgments to Derek Ross and Oughtred Society members

Apollo 11 - NASA's Lunar Lander space vehicle, with the crew Neil Armstrong, Buzz Aldrin and Michael Collins carried slide rules, for the first time in history, into space and onto the moon, July, 1969. The slide rule of choice was the aluminum pocket Pickett 600-T Dual base Log Log.

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"We went to the moon with slide rules," retiree Norman Chaffee, who worked on the spacecraft propulsion system, "I didn't even have my first full-function calculator until 1972." Note: When you watch the movie *Apollo 13* look for the engineers using slide rules
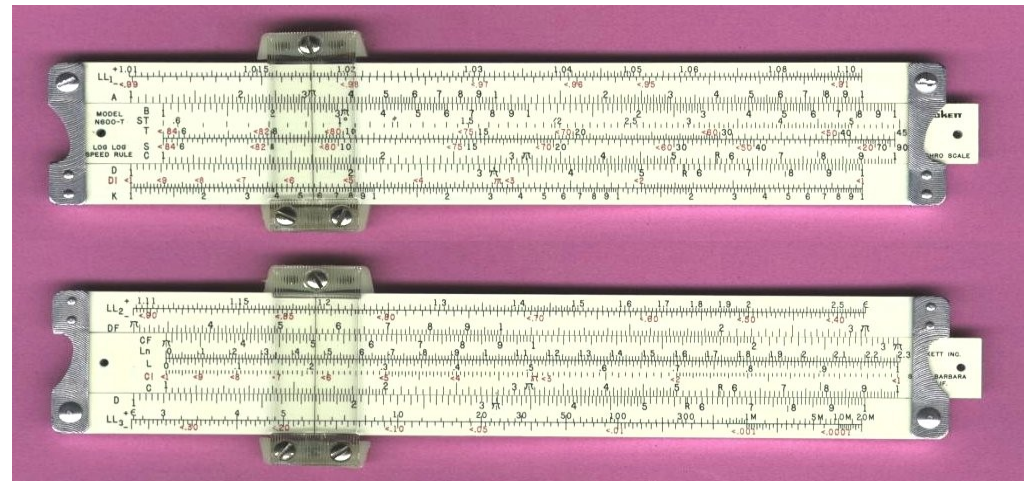
Prior to 1980, Webster's Dictionary defined the word "COMPUTER" as a PERSON who computes, typically with a slide rule.

The HP-35 "Slide Rule Calculator" was first introduced in the mid-1970's, and sold for $295*. This calculator started the demise of the slide rule industry.
*$3000 in today's money

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John Napier

William Oughtred

Amédée Mannheim

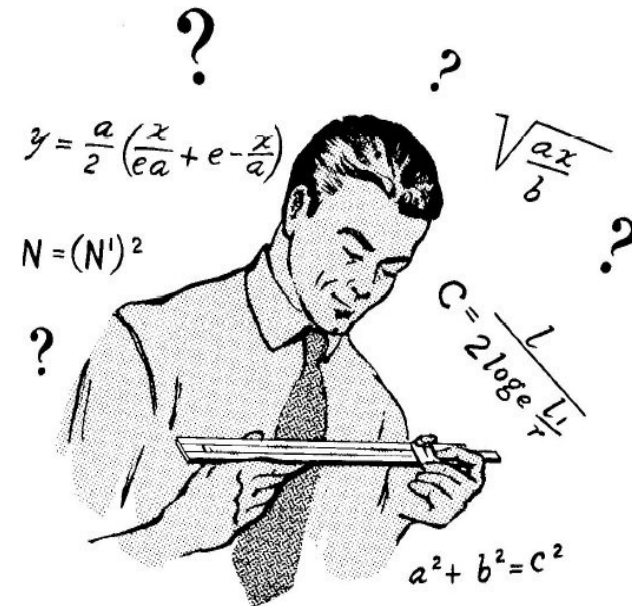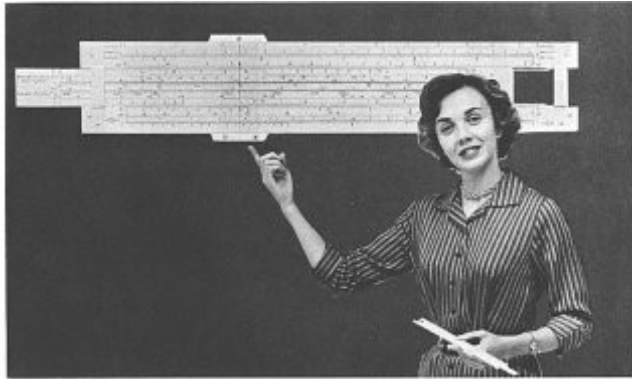# Brief History of the Slide Rule

1614 - Invention of logarithms by John Napier, Baron of Merchiston, Scotland.
1617 - Developments of logarithms 'to base 10' by Henry Briggs, Professor of Mathematics, Oxford University.
1620 - Interpretation of logarithmic scale form by Edmund Gunter, Professor of Astronomy, London.
1630 - Invention of the slide rule by the Reverend William Oughtred, London.
1657 - Development of the moving slide/fixed stock principle by Seth Partridge, Surveyor/Mathematician, England.
1775 - Development of the slide rule cursor by John Robertson of the Royal Academy.
1815 - Invention of the log log scale principle by P.M. Roget of France.
1850 - Amédée Mannheim, France, produced the modern arrangement of scales.
1886 - Dennert & Pape, Germany, introduce white celluloid as a material for inscription of scales.
1890 - William Cox of the United States patented the duplex slide rule.
c1900 - Engine divided scales on celluloid increases precision of slide rules.
1976 - The final slide rule made by K&E donated to the Smithsonian Institute, Washington, DC, USA.

Today, slide rules can be found on eBay, antique stores and estate auctions. Lost inventories of brand new slide rules turn up every year.
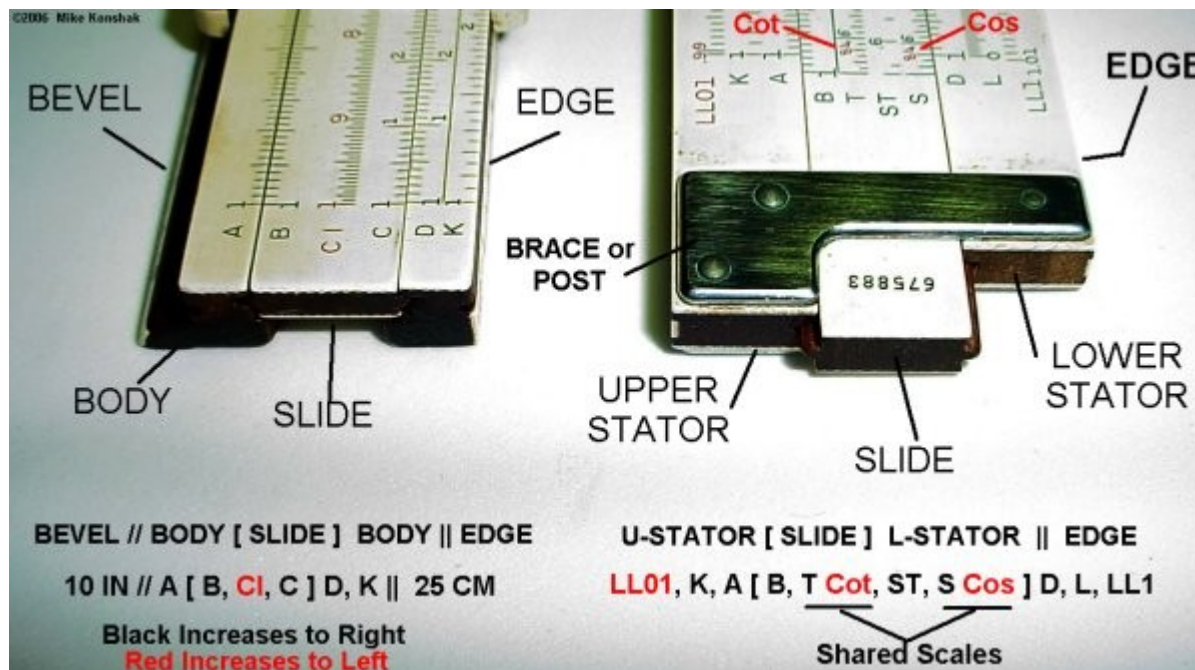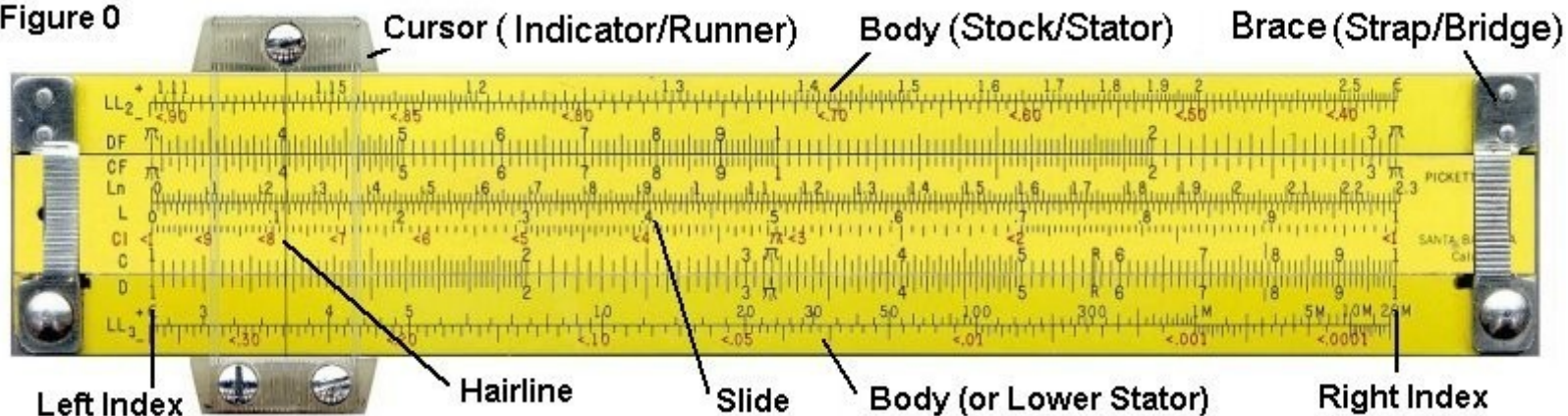
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Parts of a Slide Rule

Figure 0

Cursor (Indicator/Runner)   Body (Stock/Stator)   Brace (Strap/Bridge)

Left Index   Hairline   Slide   Body (or Lower Stator)   Right Index

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BEVEL   EDGE   EDGE

BODY   SLIDE   BRACE or POST   UPPER STATOR   SLIDE   LOWER STATOR

BEVEL // BODY [SLIDE] BODY || EDGE   U-STATOR [SLIDE] L-STATOR || EDGE

10 IN // A [B, CI, C] D, K || 25 CM   LL01, K, A [B, T Cot, ST, S Cos] D, L, LL1

Black Increases to Right
Red Increases to Left

Shared Scales

Reading the Scales

The scales on a slide rule are logarithmic, in that the spacing between divisions (the lines on the scale) become closer together as the value increases. This is why the slide rule is able to do multiplication and division rather than addition and subtraction. Compare the two sets of offset scales below in Figure B. In both cases the left index X:1 or C:1 is placed over the first whole number, either Y:2 or D:2. On a linear scale the value of any number on the X scale as read on Y is increased by 1. On a logarithmic scale, the value on any number on the C scale as read on the D scale becomes a multiple of the number under the index.

Figure B
Linear Scales
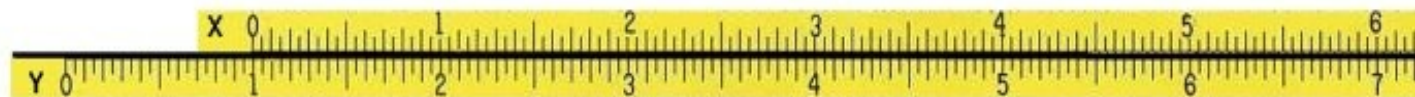
Logarithmic Scales
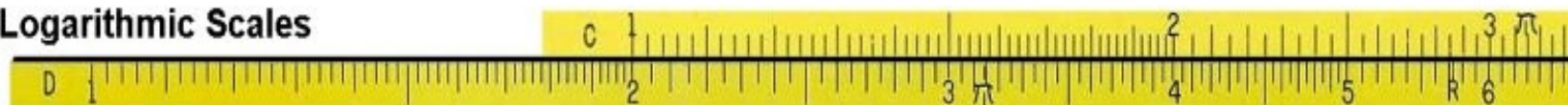
William Oughtred discovered the above characteristic in 1630, when he placed two logarithmic scales that were invented by his contemporary, Edmund Gunter, alongside each other. Thus the slide rule was born.

Reading the Scales, Cont'd.

At this point it is best to just describe how to read the scales. On almost all slide rules, the **black scales** (A, B, C, D, K, etc.) increase from left to right. The **red scales**, or inverse scales (CI, DI), increase from right to left. The pocket sized Pickett 600-ES will be used in most illustrations. The full sized Pickett N3-T for others. By the way, the Pickett 600-T (white) was taken by the Apollo 11 NASA astronauts to moon.

Figure B
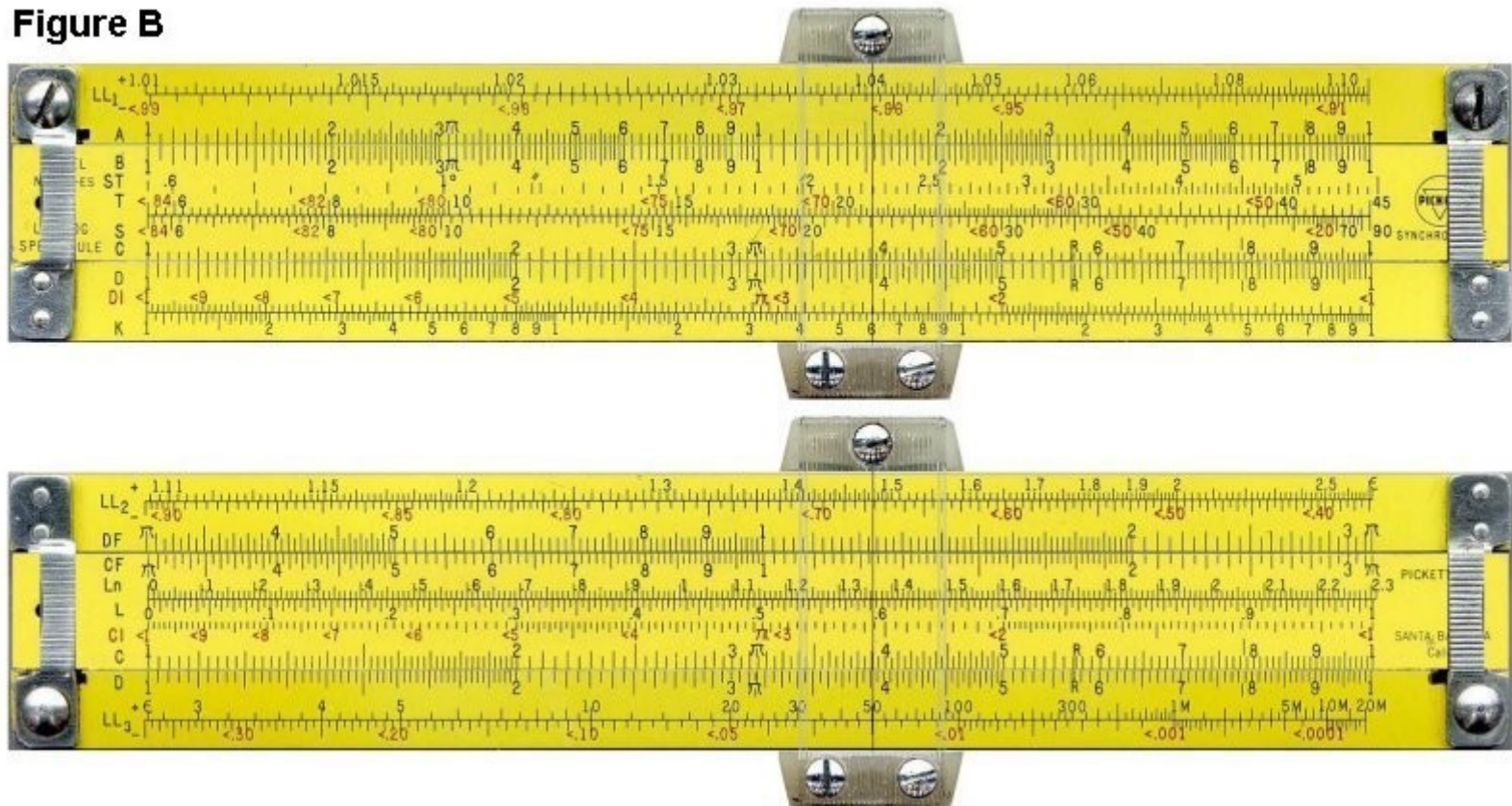
Reading the Scales, Cont'd.

Figure B
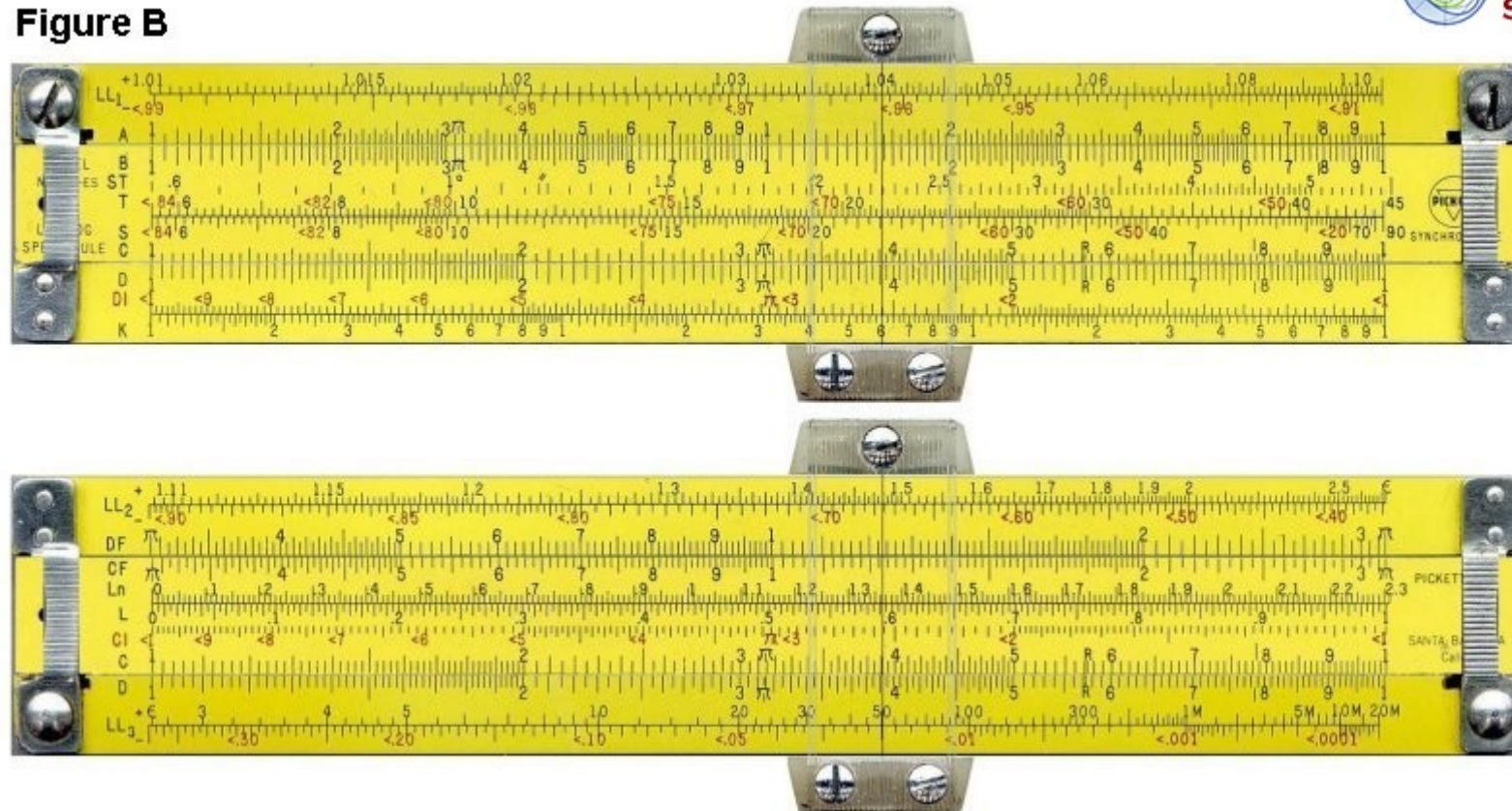
Except for 'folded', 'trig' or Log' scales, each scale begins with 1. C and D scales are single logarithmic (1-10) scales. The A and B scales are double logarithmic (1-10-100) having two cycles of 1-10, the K scale being triple logarithmic (1-10-100-1000) having three cycles of 1-10. The Primary divisions are whole numbers. The secondary divisions divide the Primary by 10, the Tertiary divisions divide the secondary by 5. Of course as you get to the end of each scale the divisions get so close together that the tertiary divisions disappear. The scales on each side of a slide rule are aligned so that calculations can be carried from one side to the other.

Approximating Values

Its important to become familiar with not only the physical divisions as marked on the scales, but in becoming able to approximate values when the hairline falls in the spacing between divisions. Positions of the slide and cursor shown in the examples will mention the label of the scale and the value on the scale, such as scale C at 1.5 will be referenced as C:1.5.

Figure C

Inverse Scales (CI, DI, -LL, Cos, etc)
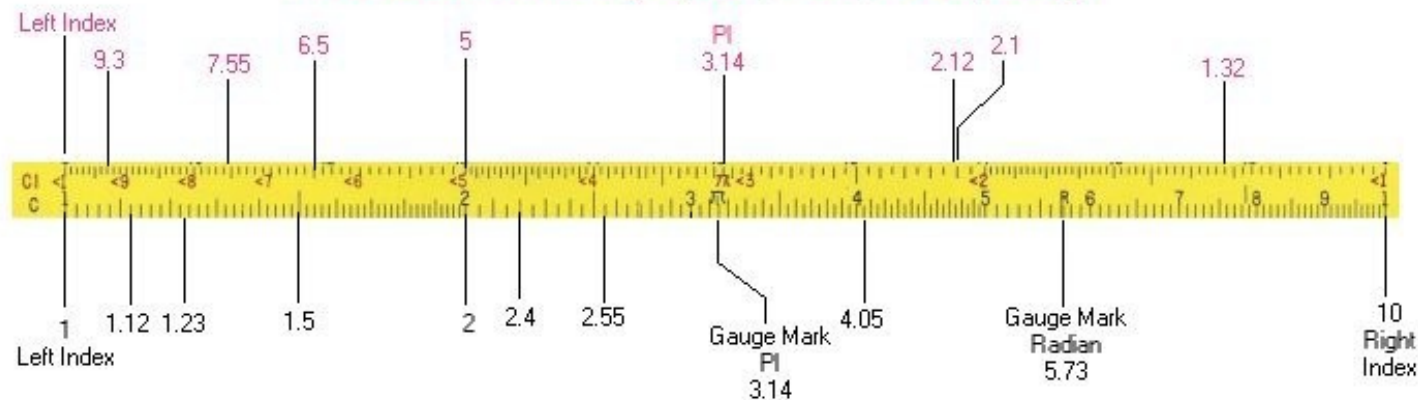
Single Logarithmic Scales (C,D)

On the left end of the scales, where the divisions are further apart, it is easy to judge the next decimal place value between in 1/10th increments (.1, .2, .3 etc) but on the other end, a hairline falling between two divisions might only be estimated as close as a half (.5).

Scientific Notation and Significant Digits

The maximum resolution of a slide rule is only 2-4 digits depending on which end of the scale is being read.

Additionally, The slide rule does not tell you where the decimal point is located in the answer. To do a calculation with a slide rule you reduce all numbers to scientific notation with 2-4 digits then use the slide rule to perform the basic operations. In a separate calculation you find the order of magnitude by combining the powers of 10. It is up to the operator to determine if the result makes sense or not.

Suppose you were given that the earth's diameter at the equator is 7,926.41 miles and you are asked to find the circumference using

$C = \pi D$

The value for π, for example is 3.14159... but for slide rule calculations we round that to 3.1 or 3.14.

We would round D= 7926.41 to 7.93 x 1000

or 7.93 x 10^3
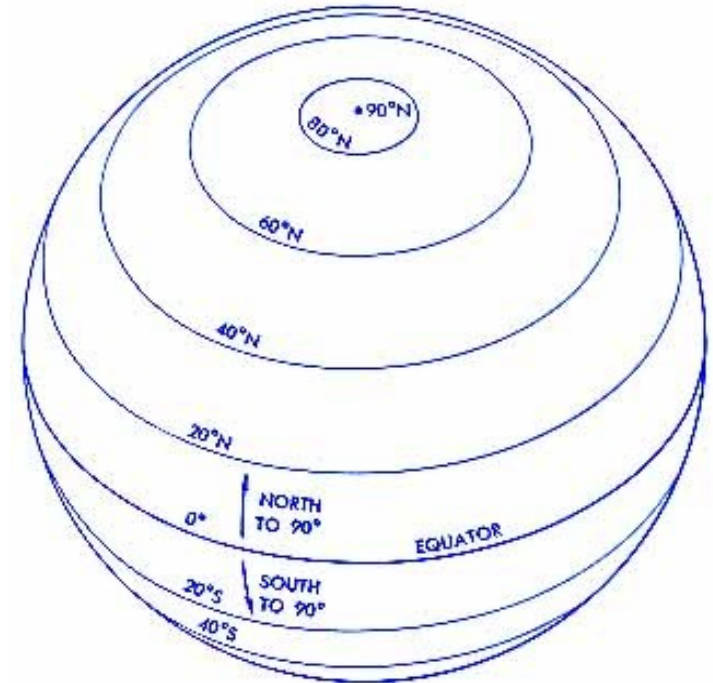
Scientific Notation and Significant Digits, cont'd

Now its a simple task of using the slide rule to multiply 3.14 x 7.92 x 1000 The final result on the slide rule would have read 2.49, but we can easily mentally calculate that 3 x 8 = 24, so what you are seeing should be 24.9. We then add the 3 decimal places (the zero's in 1000) to shift the decimal point to 24,900 miles. In talking with someone you might further round off your answer to say that the earth's circumference at the equator is about 25,000 miles, and for all practical purposes you'd be correct. Your calculator gave you an answer of 24,868.8, but you'd be a real boor if you rattled off that number to your friends. The difference between 24,900, 25,000 or 24,868.8 is less than a one-half of one percent, so the error is very small. Remember we made it to the moon and engineered every structure you see before 1970 using slide rule accuracy.

The curse and blessing of modern calculators is that this type of thinking is no longer necessary or encouraged by educators. Students just hit buttons and copy down what is on the display. Of course the fact that most of the digits in the display of a calculator is useless noise does not bother most students. Modern students are not challenged to judge whether or not the calculator's result is in the right range, and errors can be propagated
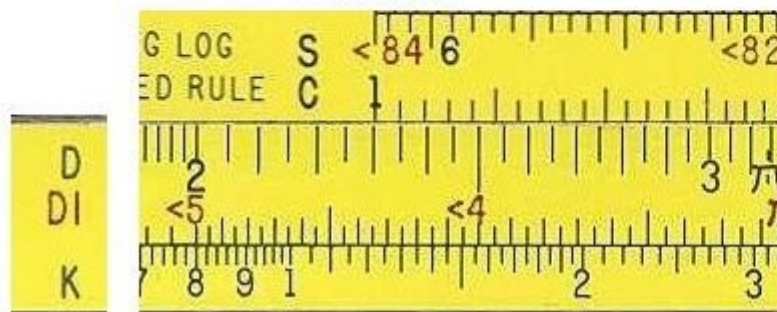
1. Simple Multiplication (uses C and D scales)

Example: calculate 2.3 × 3.4
- Slide the leftmost Index '1' on C over 2.3 on the D scale.
- Move the cursor to 3.4 on the C scale.
- The cursor is on the D scale just a bit over 7.8 or 7.82. This is the answer.

Figure 1

C:1 Index   C:3.4
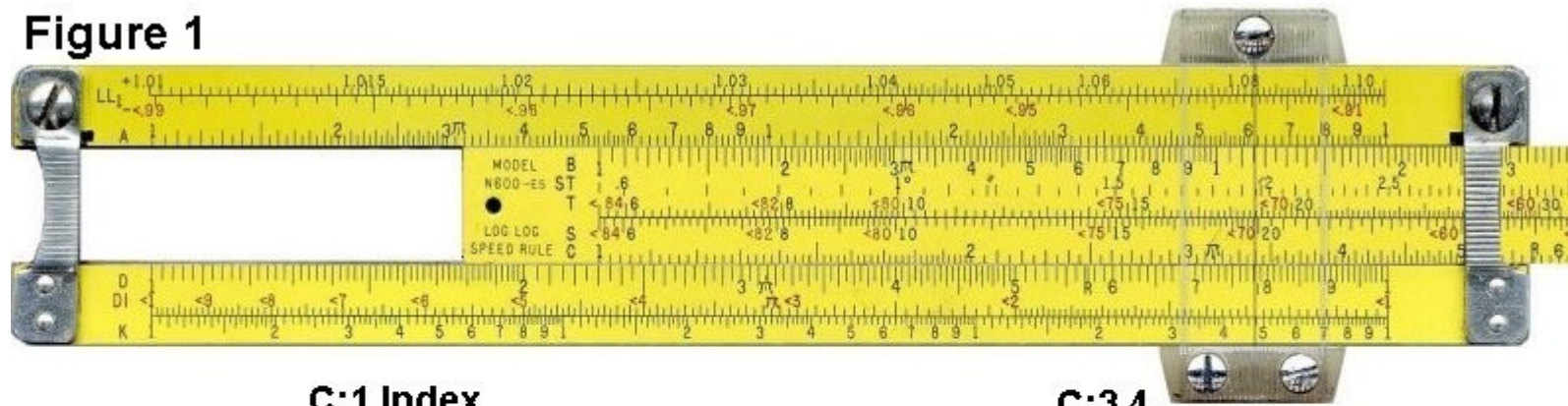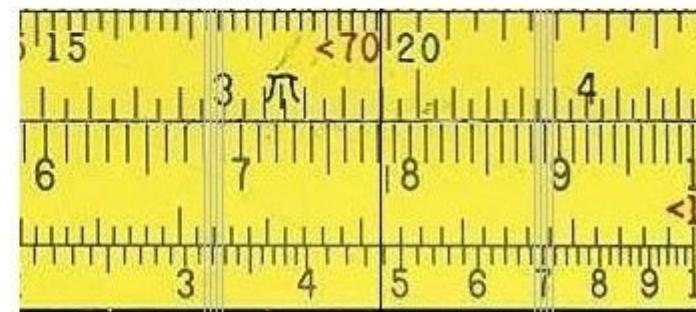
D:2.3   Read D:7.2

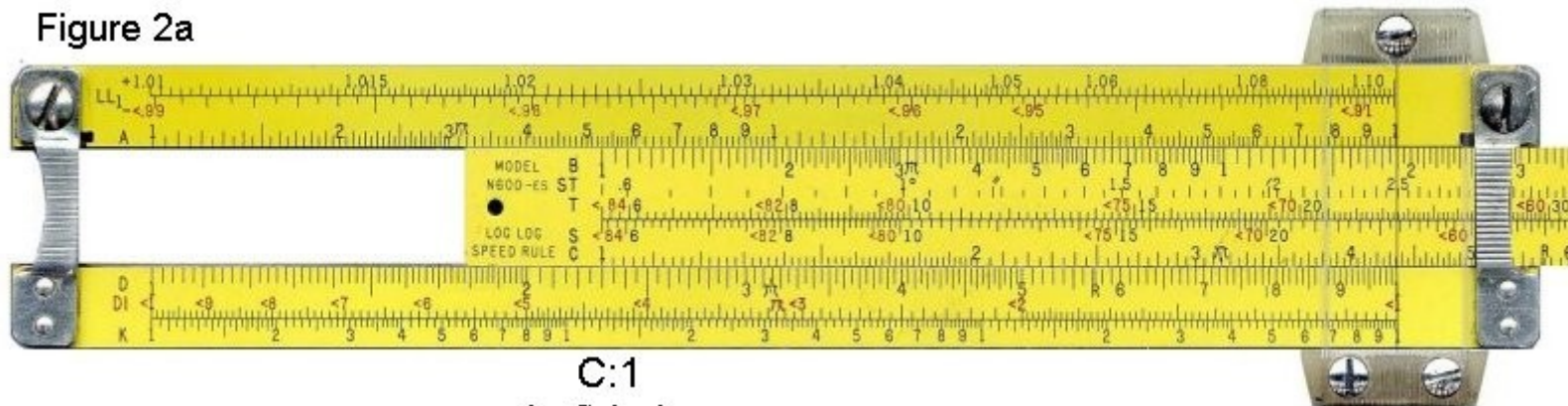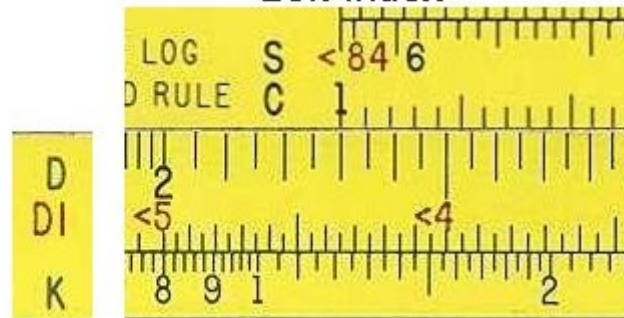## 2. 'Wrap-Around' Multiplication (uses C and D scales)

Example 2a: calculate 2.3 × 4.5

- Move the left Index on C to 2.3 on the D scale.
- Try to move the cursor to 4.5 on the C scale. The cursor is blocked by the brace (also called strap or bridge).
- The target C:4.5 is off the D scale. The right Index must now be used.

Figure 2a

C:1
Left Index

D:2.3
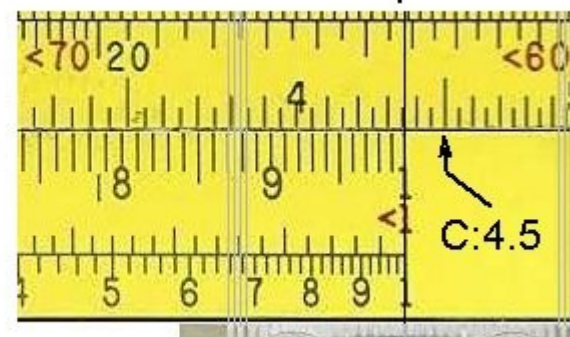
Cursor blocked at right Index

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Example 2b: calculate 2.3 × 4.5

- Move the right Index on C (C:1) to over 2.3 on the D scale (D:2.3)
- Slide the cursor to 4.5 on the C scale (C:4.5)
- On the D scale, you'll see that the hairline is between divisions. Estimate the answer to 1.035.
- Do a rough approximation by rounding 2.3 to 2 and 4.5 to 5.
- We mentally calculate 2 × 5 = 10, so we adjust the decimal place to get 10.35 or 10.4.

Figure 2b

C:4.5

C:1
Right Index

Close up of scale divisions
for extrapolation

Ans D:1.035

D:2.3

1.02   1.03   1.04   1.10
1.035
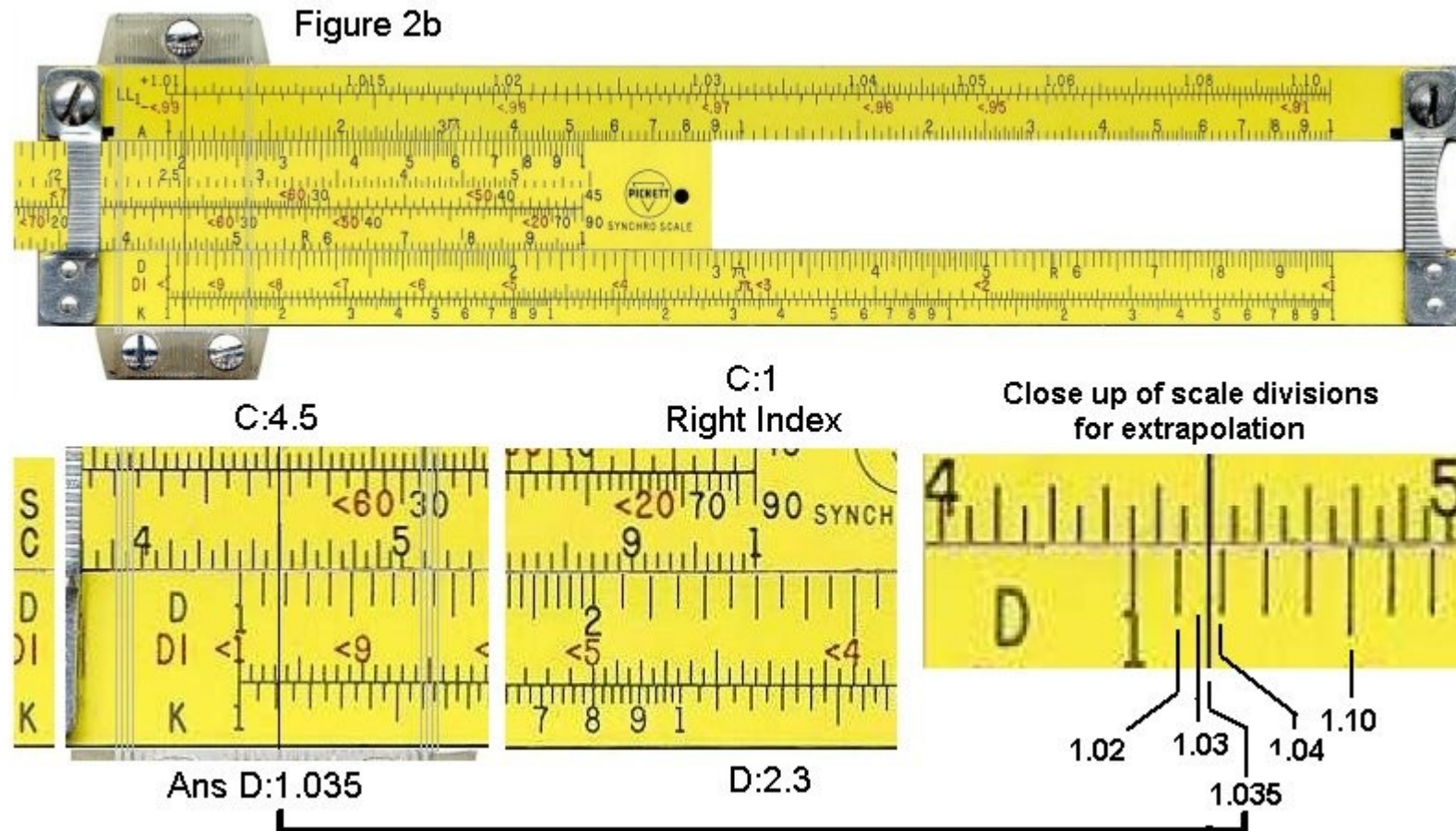
3. Folded-Scale Multiplication (uses C, D, CF and DF scales)

Example 3: calculate 2.3 × 4.5

- Slide the leftmost Index, '1', on C over the 2.3 on the D scale (D:2.3).
- We can't move the cursor to 4.5 on the C scale; it's out of range. We can use the folded scales to get this answer.
- Move the cursor to 4.5 on the CF scale (CF:4.5).
- The cursor is now at 1.04 on the DF scale (DF:1.04).
- We know the correct answer is near 2 × 5 = 10, so we adjust the decimal place to get 10.4.

Figure 3   CF:4.5   Read DF:1.04

C:1 Index over D:2.3
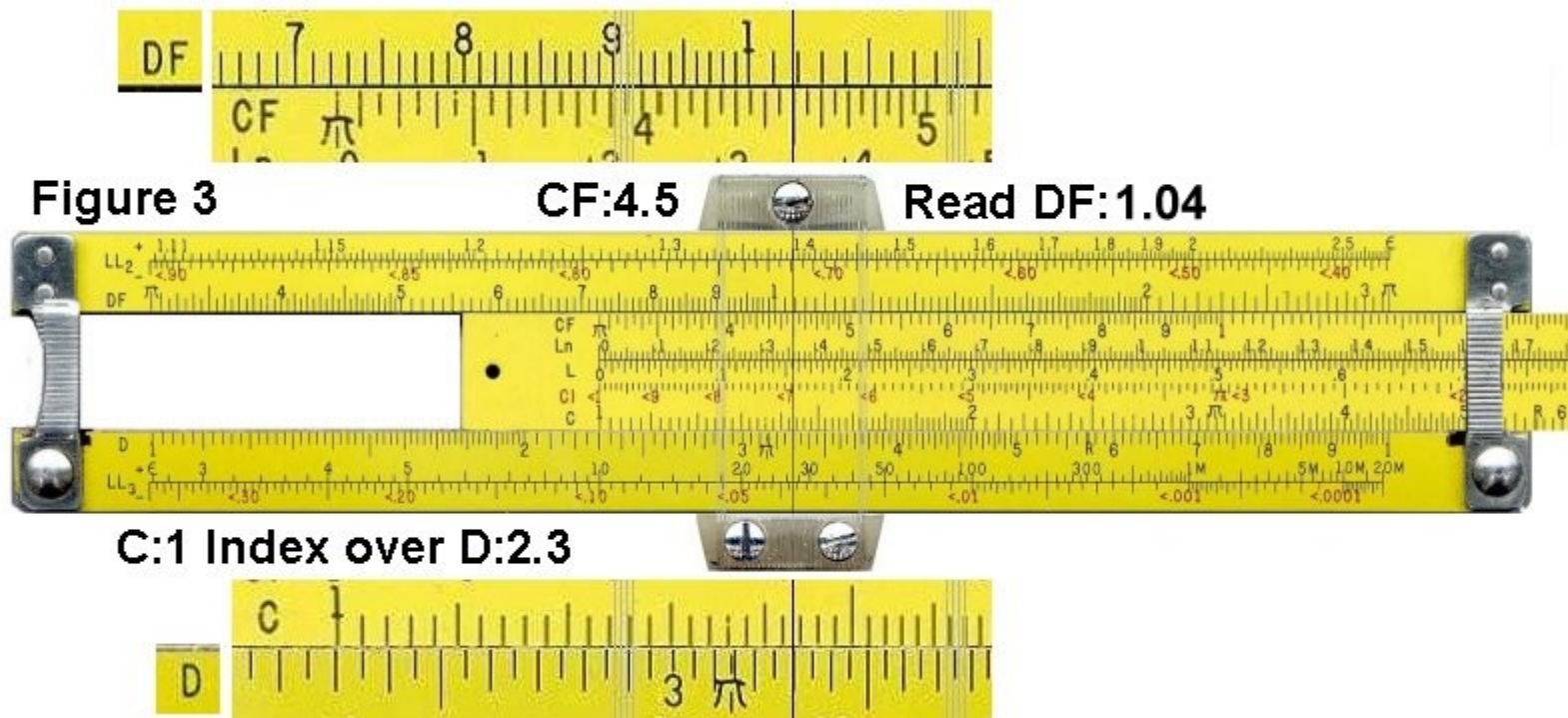
4. Multiplication by π (uses D and DF scales)

Example 4: calculate 123 × π

- Move the cursor to 1.23 on the D scale.
- The cursor is now at 3.86 on the DF scale.
- We know that the correct answer is near 100 × 3 = 300, so we adjust the decimal place to get 386.

Figure 4

D:1.23

Read DF:3.86
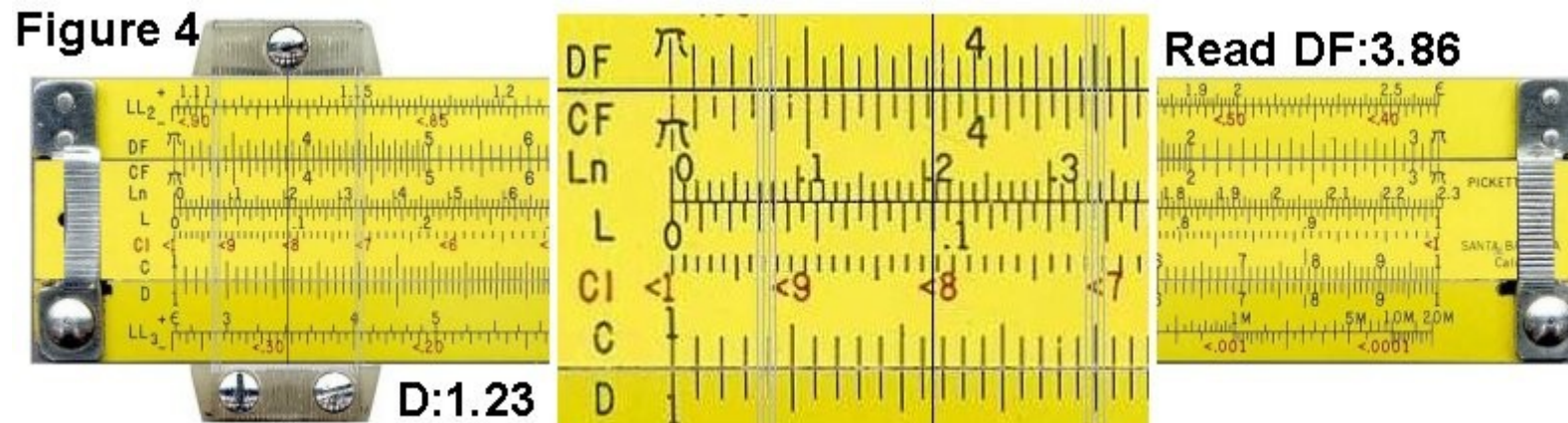
5. Simple Division (uses C and D scales)

Example 5: calculate 4.5 / 7.8

- Move the cursor to 4.5 on the D scale.
- Slide 7.8 on the C scale to the cursor.
- Move the cursor to either the leftmost or rightmost '1' on the C scale, whichever is in range. In this case, you would move it to the rightmost '1'.
- The cursor is now at 5.76 on the D scale.
- We know that the correct answer is near 4/8 = 0.5, so we adjust the decimal place to get 0.576.

Figure 5

C:7.8   C:1 Index

D:4.5   Read D:5.76

6. Reciprocal (uses C and CI scales)

Example 6: calculate the reciprocal of 7.8, or 1/7.8

- Move the cursor to 7.8 on the CI scale. Note that the CI scale increases from right to left, as indicated by the '<' symbols before the numbers.

- The cursor is now at 1.28 on the C scale.

- We know that the correct answer is near $1/10 = 0.1$, so we adjust the decimal place to get 0.128.

Figure 6

CI:<7.8
Read C:1.28
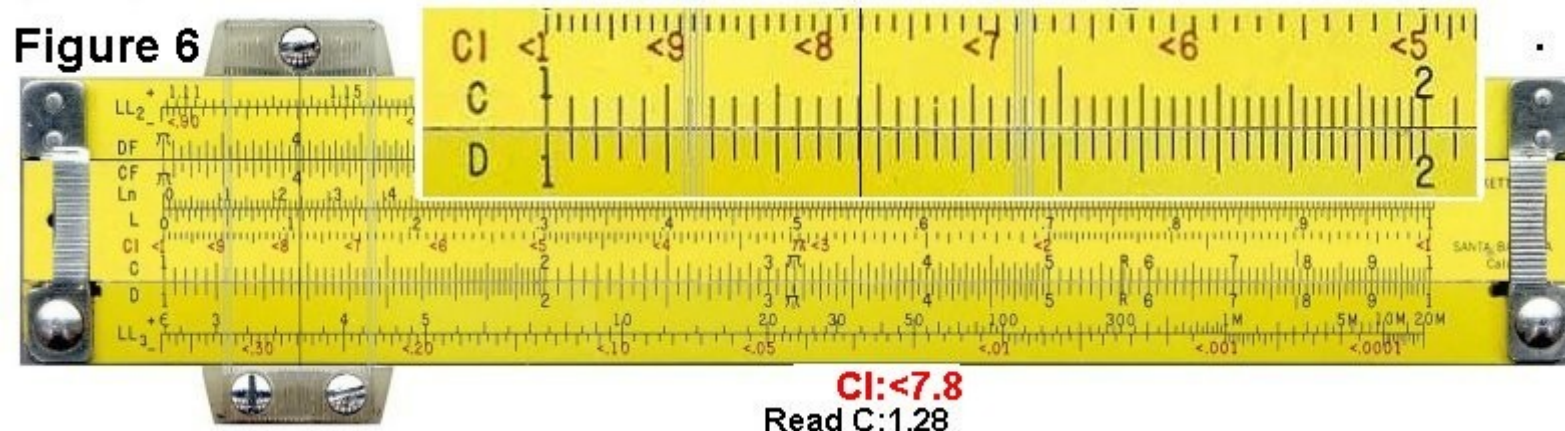
Trigonometry

7. Sin(x) for angles between 5.7° and 90° (uses S and C scales)

    Example 7: calculate sin(33°)

-     Move the cursor to 33 on the S scale.
-     The cursor is at 5.45 on the C scale.
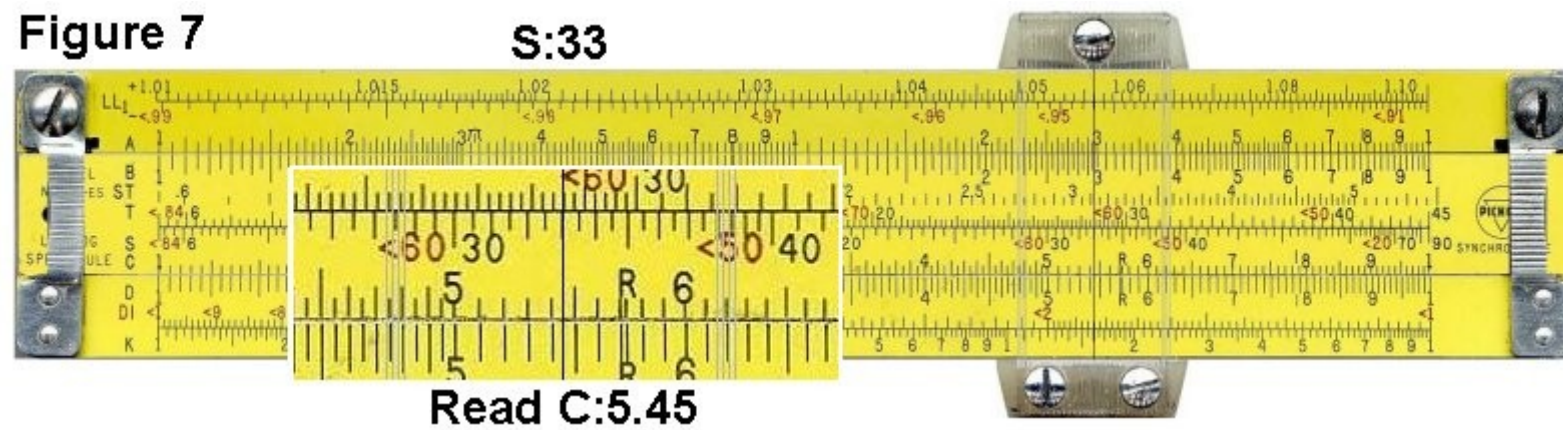-   We know that the correct answer for a sin in this range is between 0.1 and 1, so we adjust the decimal place to get 0.545.

Figure 7
S:33
Read C:5.45

8. Cos(x) for angles between 5.7° and 90° (uses S and C scales)

Example 8: calculate cos(33°).

- The cos scale shares the sin S scale. Instead of increasing from left to right like the sin scale, cos increases from right to left. This is indicated on the slide rule by '<' characters which remind you that the number in increasing 'backwards'.

- Move the cursor to <33 on the S scale.

- The cursor is now at 8.4 on the C scale.

- We know that the correct answer for a cos in this range is between 0.1 and 1, so we adjust the decimal place to get 0.84.

Figure 8

S(cos): <33

Read C:8.4

9. Tan(x) for angles between between 5.7° and 45° (uses T and C scales)

Example 9: calculate tan(33°) .

- Move the cursor to 33 on the T scale.
- The cursor is now at 6.5 on the C scale.
- We know that the correct answer for a tan in this range is between 0.1 and 1, so we adjust the decimal place to get 0.65.
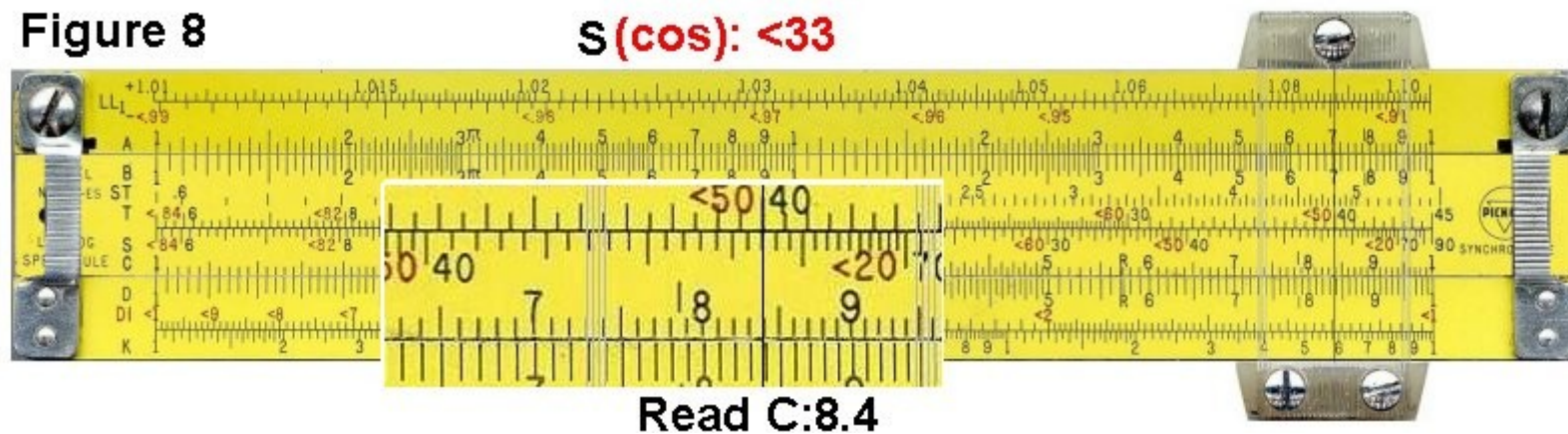
Figure 9

T:33

Read C:6.5
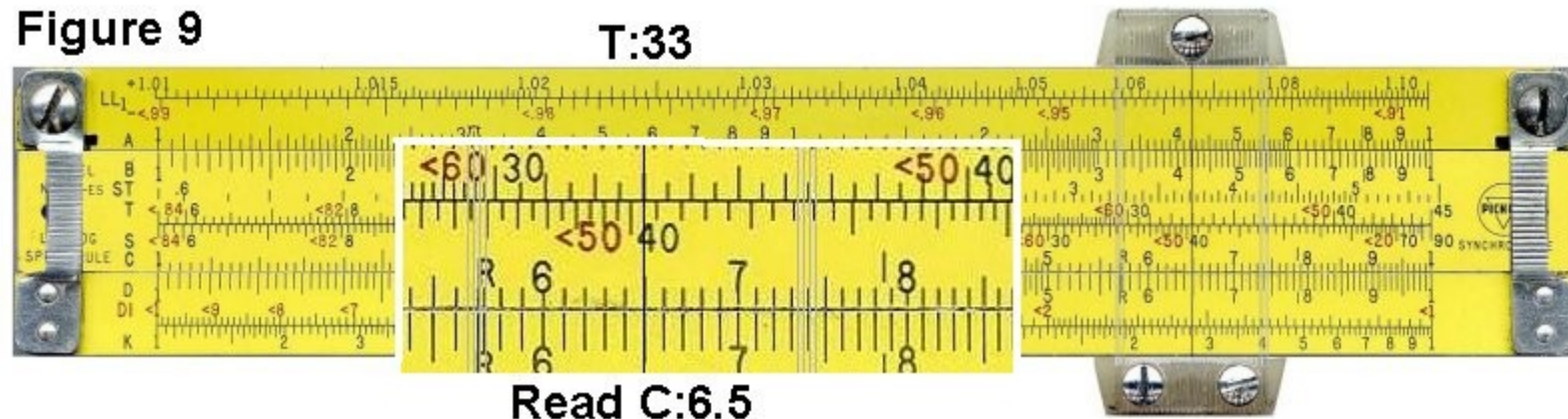
10. Tan(x) for angles between between 45° and 84° (uses backward T and CI scale)

Example 10a: calculate tan(63°) (Figures 10a and 10b)

- Move the cursor to <63 on the T scale. Note that this range increases from right to left, as indicated by the '<' before the numbers.
- The cursor is now at <1.96 on the DI scale. Figure 10a

Go to the next slide Please

Figure 10a   T:63
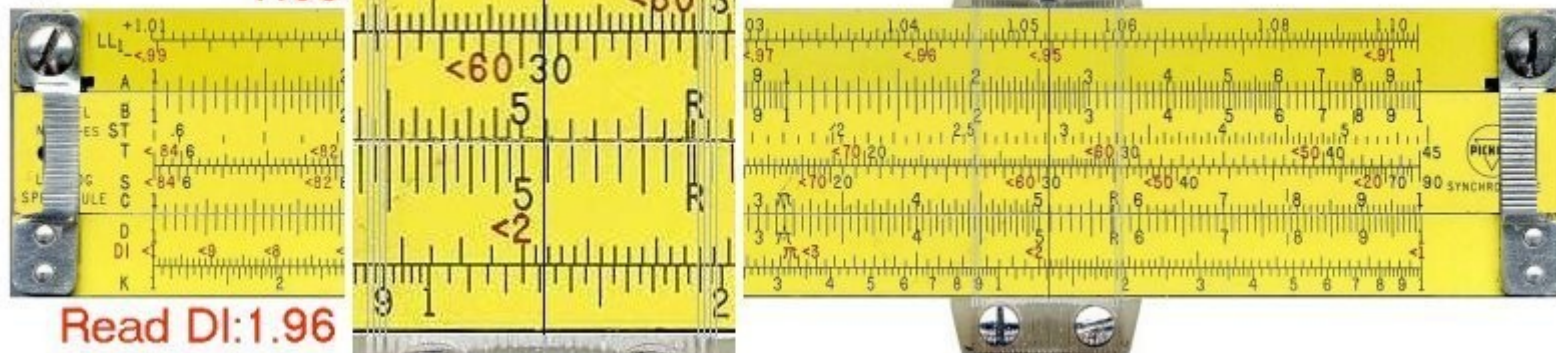
Read DI:1.96

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Example 10a: calculate tan(63°)

- Move the cursor to <63 on the T scale. Note that this range increases from right to left, as indicated by the '<' before the numbers.
- The cursor is now at <1.96 on the DI scale. Figure 10a
- Flip to the other side of the slide rule. The cursor is also at <1.96 on the CI scale. Figure 10b
- We know that the correct answer for a tan in this range is between 1 and 10, so we don't need to adjust the decimal place.

Figure 10b

T:63 (other side)

Flip Over, Read CI:1.96

11. Tan(x) for angles between between 45° and 84° (uses forward T and C scale)

Example 11: calculate tan(63°).

- Move the cursor to 63 on the forward T scale. This scale increases from left to right.
- The cursor is now at 1.96 on the C scale.
- We know that the correct answer for a tan in this range is between 1 and 10, so we don't need to adjust the decimal place.
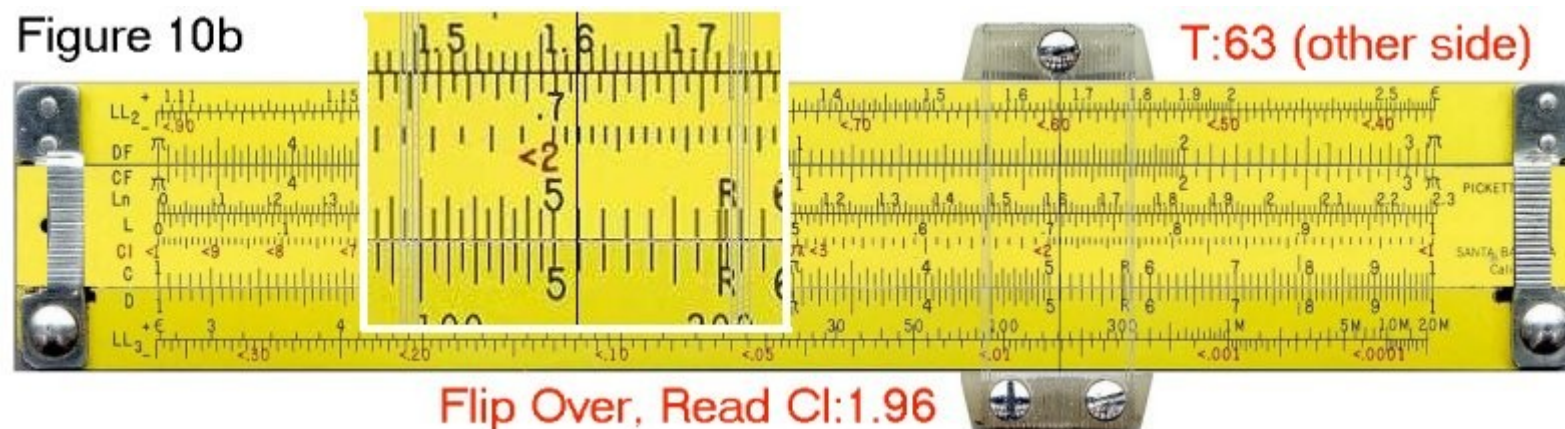

Figure 11   T:63

Read C:1.96
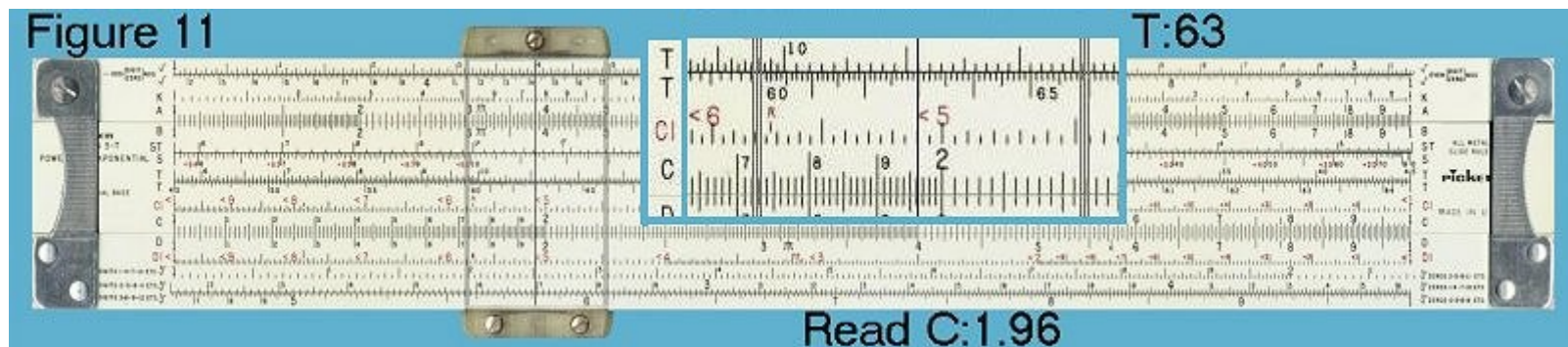
12. Sin(x) and tan(x) for angles between 0.6° and 5.7° (using the ST and C scales)

In this range, the sin and tan functions are very close in value, so a single scale can be used to calculate both.

Example: calculate sin(1.5°)

- Move the cursor to 1.5 on the ST scale.
- The cursor is now at 2.62 on the C scale.
- We know that the correct answer for a sin in this range is between 0.01 and 0.1, so we adjust the decimal place to get 0.0262.

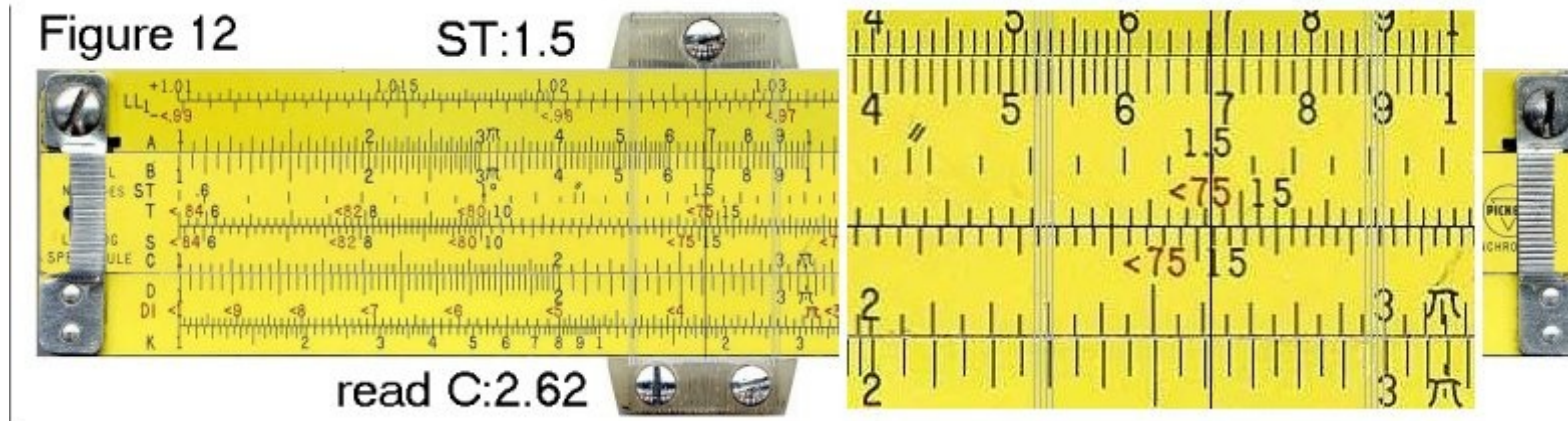Figure 12   ST:1.5   read C:2.62

13. Sin(x) and tan(x) for other small angles (using C and D scales)

For small angles, the sin or tan function can be approximated closely by the equation:

$$\sin(x) = \tan(x) = x / (180/\pi) = x / 57.3.$$

Knowing this, the calculation becomes a simple division. This technique can also be used on rules without an ST scale.

Continues on next slide:

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13. Sin(x) and tan(x) for other small angles (using C and D scales) Cont'd

Example: calculate sin(0.3°)
- Move the cursor to 3 on the D scale.
- Slide 5.73 on the C scale to the cursor. Most rules have a tick labeled 'R' at this point.
- Move the cursor to either the leftmost or rightmost '1' on the C scale, whichever is in range.
- The cursor is now at 5.24 on the D scale.
- We know that the correct answer is near 0.3 / 60 = 0.005, so we adjust the decimal place to get 0.00524.

Figure 13   C:5.7 (R)   C:1 Index

D:3   Read 5.24
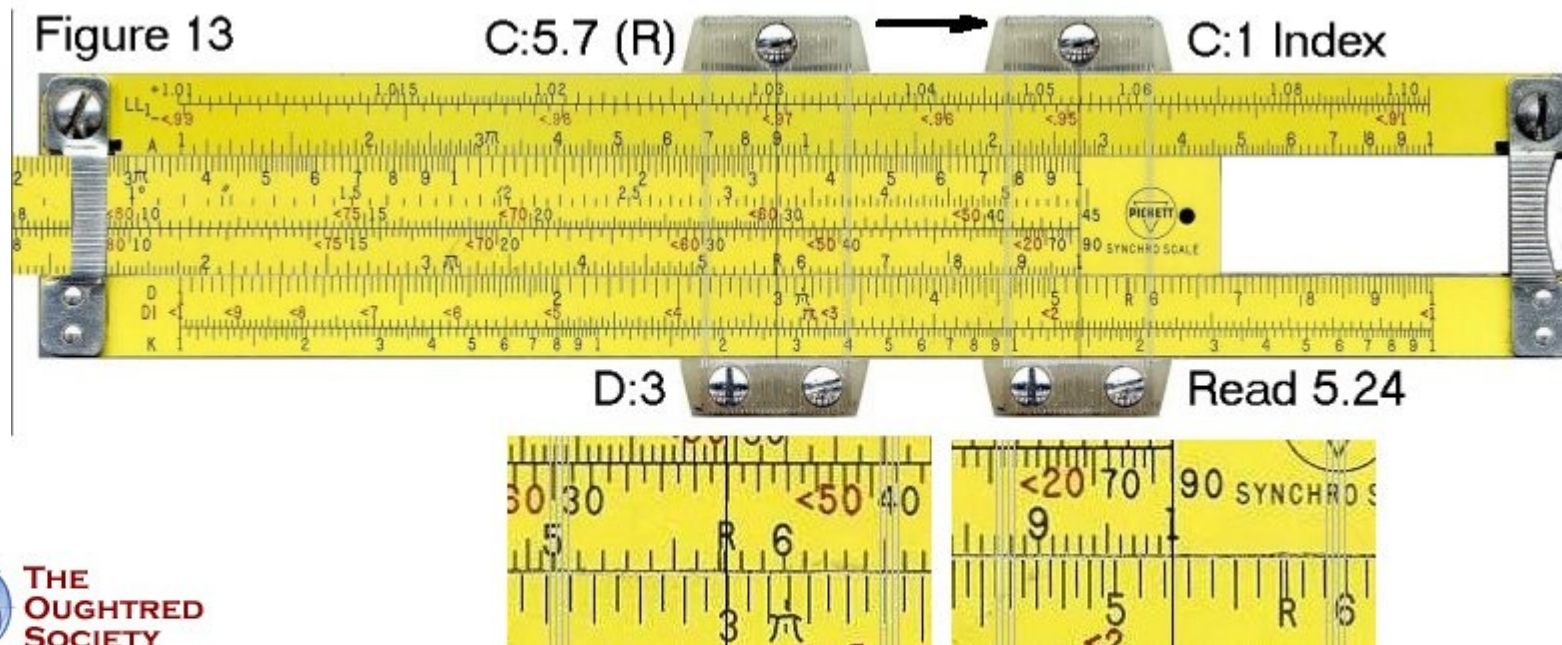
14. Square (uses C and B scales)
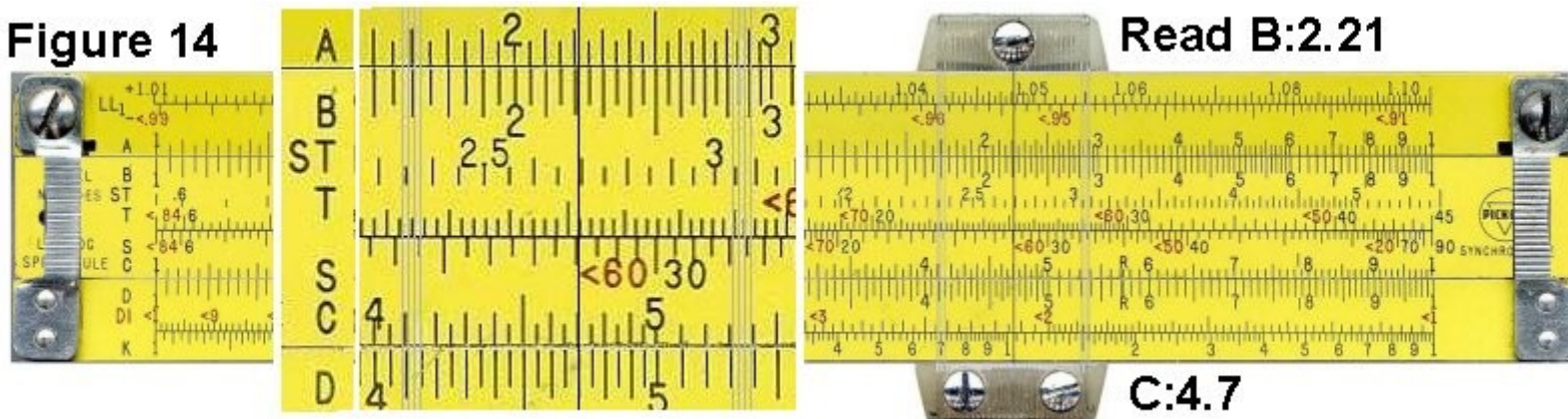
Example 14: calculate 4.7^2

- Move the cursor to 4.7 on the C scale.
- The cursor is now at 2.2 on the B scale.
- We know that the correct answer is near $5^2 = 25$, so we adjust the decimal place to get 22.

Figure 14

Read B:2.21

C:4.7

15. Square Root (uses C and B scales)

Example 15a: calculate √4500

- You will notice that the B scale has two similar halves. The first step is to decide which half to use to find a square root.
- The left half is used to find the square root of numbers with odd numbers of digits or leading zeros after the decimal point. The right half is used for numbers with even numbers of digits or leading zeros. Since 4500 has an even number of digits, then we'll use the right half of the scale.
- Move the cursor to 4.5 on the right half of the B scale.
- The cursor is now at 6.7 on the C scale.
- We know that $70^2 = 3600$, which is in the ballpark of 4500. Therefore we adjust the decimal point to get a result of 67.

Odd number of digits use left half of A/B   Even digits use right half of A/B

B:4.5

Read C:6.7

Figure 15
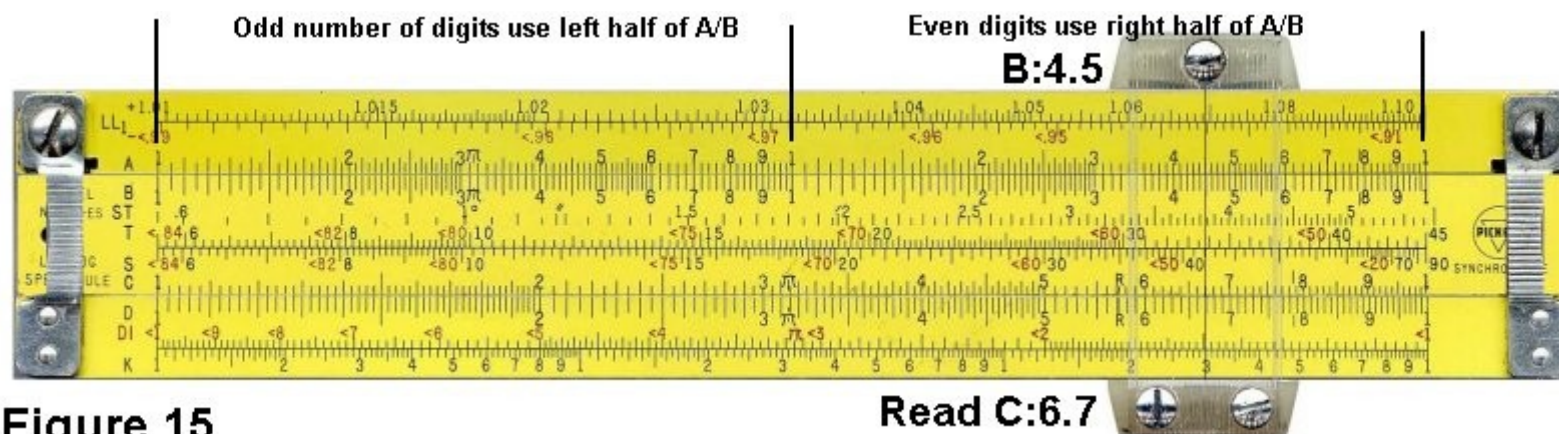
15. Square Root (uses C and B scales) cont'd

Example 15b: calculate √450

- Try it a again with a three digit number.
- Move the cursor to 4.5 on the left half of the B scale.
- The cursor is now at 2.12 on the C scale.
- We know that $20^2 = 400$, which is in the ballpark of 450. Therefore we adjust the decimal point to get a result of 21.2

Figure 15b

Odd number of digits — B:4.5

Even number of digits

Read C:21.2

450 has 3 digits, or an odd number of digits
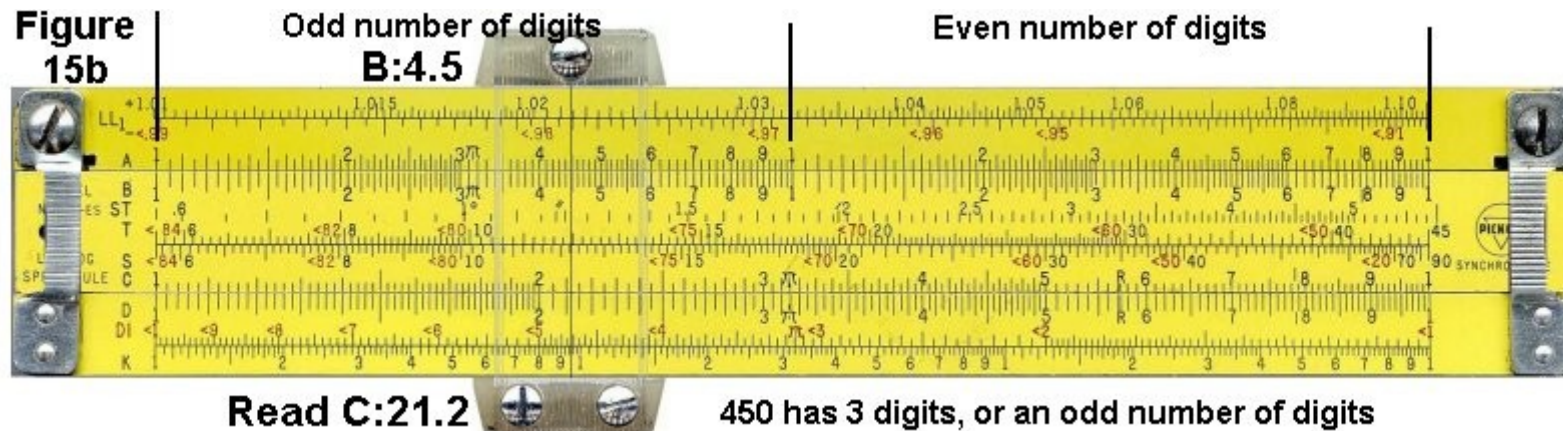
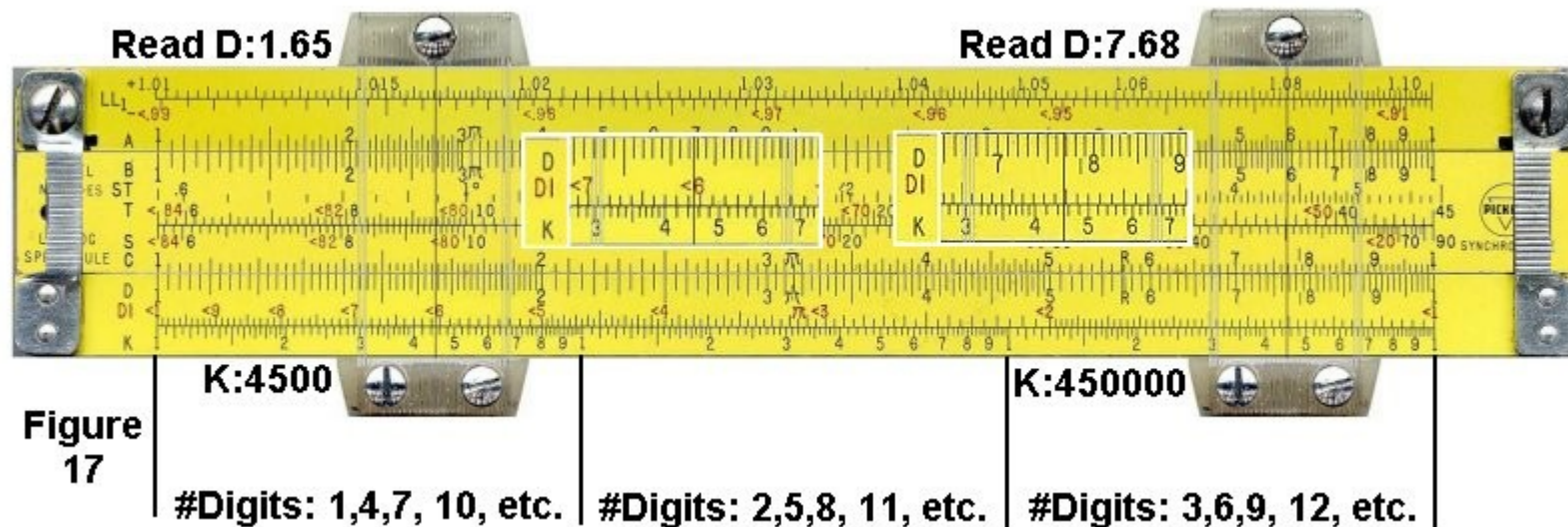## 16. Cube (uses D and K scales)

Example 16: calculate 4.7 [3]

- Move the cursor to 4.7 on the D scale.
- The cursor is now at 1.04 on the K scale.
- We know that the correct answer is near 5 x 5 x 5, which, to further approximate, is near 5 x 5 x 4 = 5 x 20 = 100. Therefore we adjust the decimal point to get a result of 104.

Figure 16

D:4.7   Read K:1.04
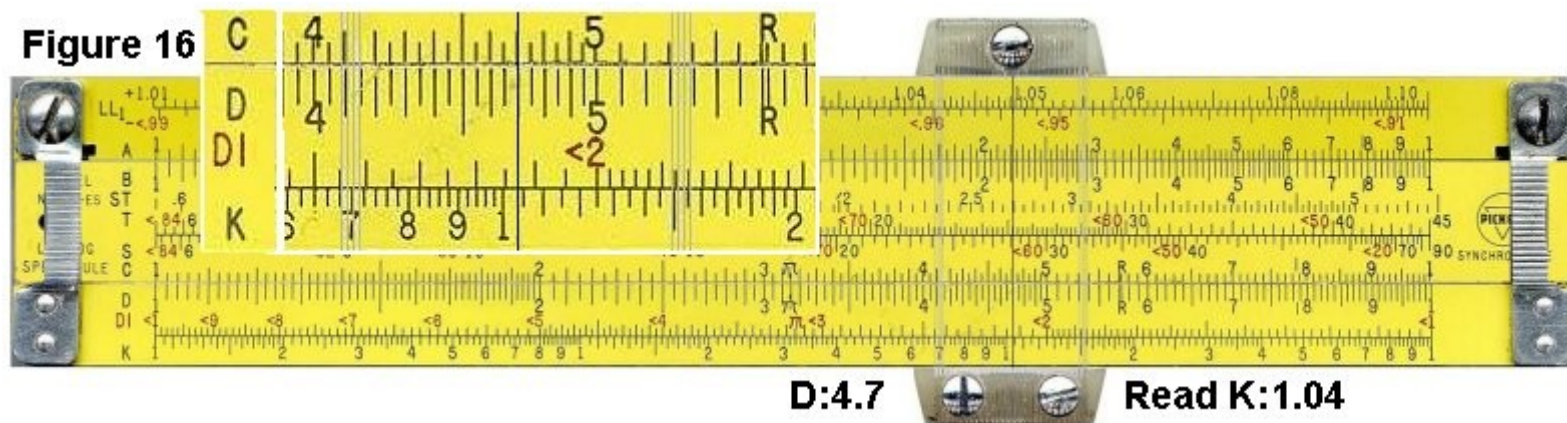
17. Cube Root (uses D and K scales)

-     You will notice that the K scale has three similar thirds. The first step is to determine which third to use to find the cube root.
-     The first third is used to find the cube root is numbers with one digit. You can cycle through the thirds, increasing the number of digits by one for each third, to find which part to use. Just like having a line of people and you count off into 3's.

Read D:1.65   Read D:7.68

K:4500	K:450000

Figure 17

#Digits: 1,4,7, 10, etc.	#Digits: 2,5,8, 11, etc.	#Digits: 3,6,9, 12, etc.

17. Cube Root (uses D and K scales) Cont'd

Example 17a: calculate $\sqrt[3]{4500}$ (Figure 17 - left)

- For the value of 4500, which has 4 digits, we cycle through the thirds and find that we would use the first third.
- Move the cursor to 4.5 on the first third of the K scale.
- The cursor is now at 1.65 on the D scale.
- We can take a guess that the correct answer is around 10. The cube of 10 is 1000 and the cube of 20 is 8000. Thus we know that the correct answer is between 10 and 20, therefore we can move the decimal place and get the correct result of 16.5.

Figure 17

Read D:1.65   Read D:7.68

K:4500   K:450000

#Digits: 1,4,7, 10, etc. | #Digits: 2,5,8, 11, etc. | #Digits: 3,6,9, 12, etc.
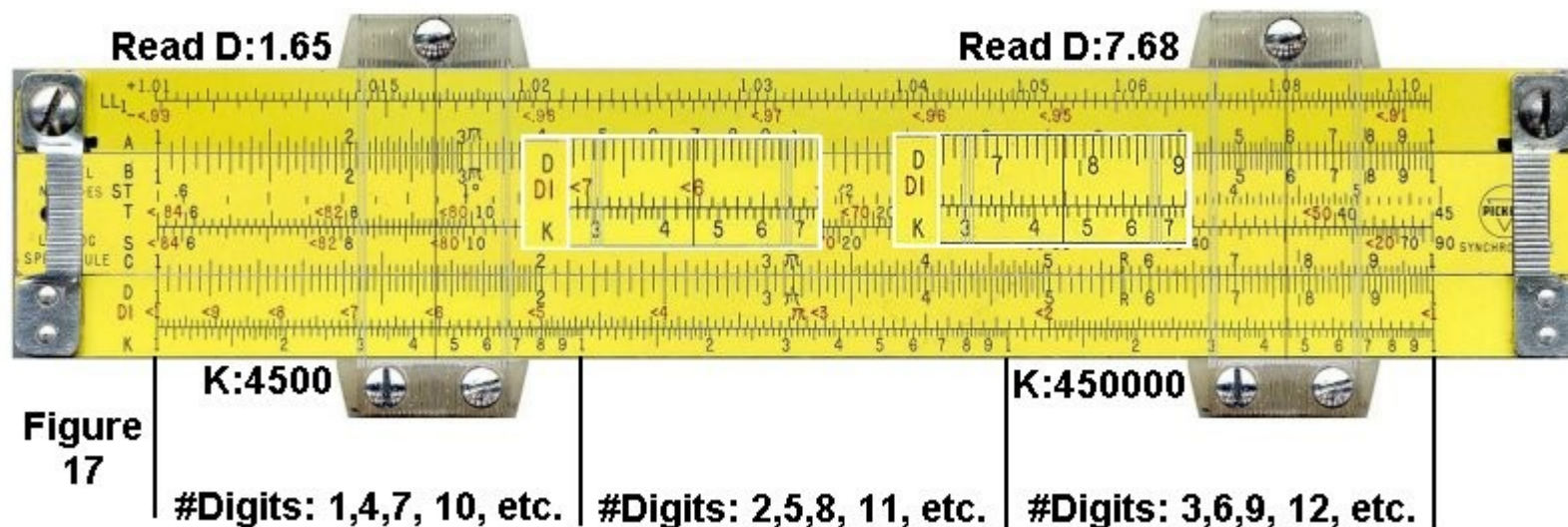
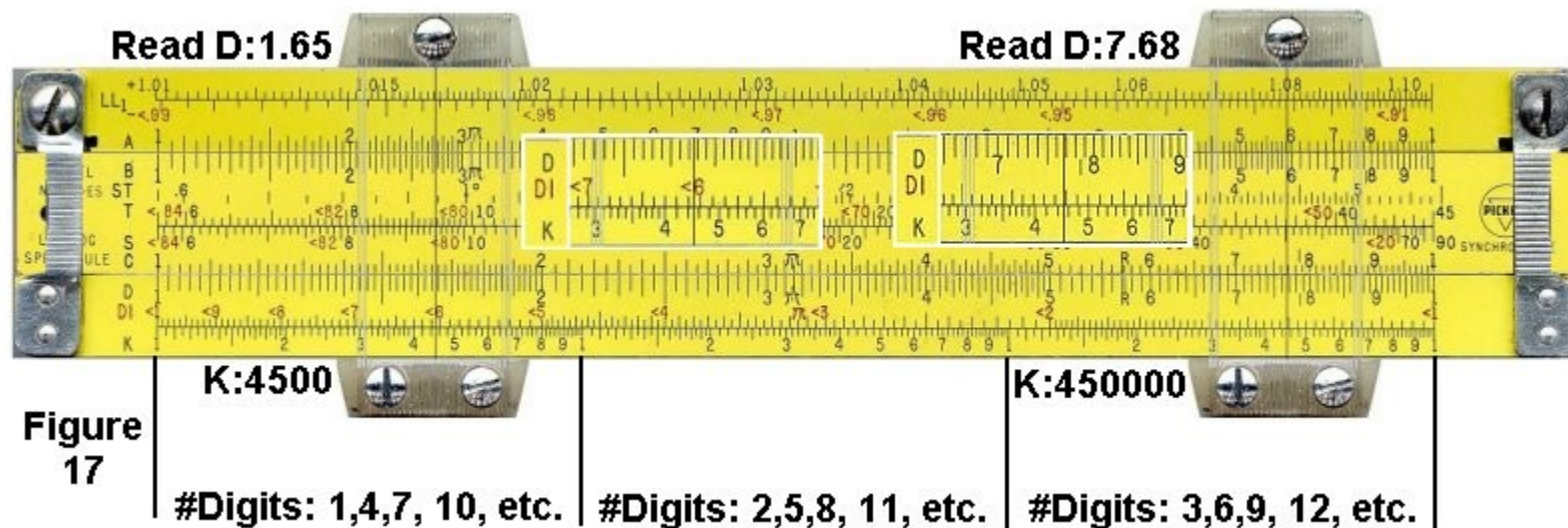**Example 17b: calculate $\sqrt[3]{450000}$ (Figure 17 - right)**

- For the value of 450000, which has 6 digits, we cycle through the thirds and find that we would use the third third.
- Move the cursor to 4.5 on the third third of the K scale.
- The cursor is now at 7.68 on the D scale.
- We can take a guess that the correct answer is around 10. The cube of 10 is 1000 and the cube of 100 is 1000000. Thus we know that the correct answer is between 10 and 100, therefore we can move the decimal place and get the correct result of 76.8.

Read D:1.65   Read D:7.68

K:4500   K:450000

Figure 17

#Digits: 1,4,7, 10, etc. | #Digits: 2,5,8, 11, etc. | #Digits: 3,6,9, 12, etc.

Log-Log Scales

Log-log scales are used to raise numbers to powers. Unlike many of the other scales, log-log scales can't be learned simply be memorizing a few rules. It is necessary to actually understand how they work. These examples are intended to gradually introduce you to the concepts of log-log scales, so you gain that understanding. Hopefully, the power of 10 examples don't bore you, as they lay the foundation for later examples.

Since there are many slight variations of log-log scales on different slide rules, I'll refer only to the scales found on the Pickett N3, Pickett N600 and Pickett N803 slide rules (among others).

Another interesting aspect of LL scales is that the decimal point is "placed." That is, you don't have to figure out afterwards where the decimal point belongs in your result. The disadvantage to this is that LL scales are limited in the numbers they can calculate. Typically, the highest result you can get is about 20,000, and the lowest is 1/20,000 or 0.00005. One exception to this is the Picket N4, which goes up to 10^{10}.

18. Raising a Number to Powers of 10 (N>1)

To raise a number to the power of 10, simply move the cursor to the number and look at the next highest LL scale. (These examples are for numbers greater than 1.)

Example 18a: calculate 1.35^{10} (uses LL2 and LL3 scales)
- Move the cursor to 1.35 on the LL2 scale.
- The cursor is at 20.1 on the LL3 scale. This is the correct answer.
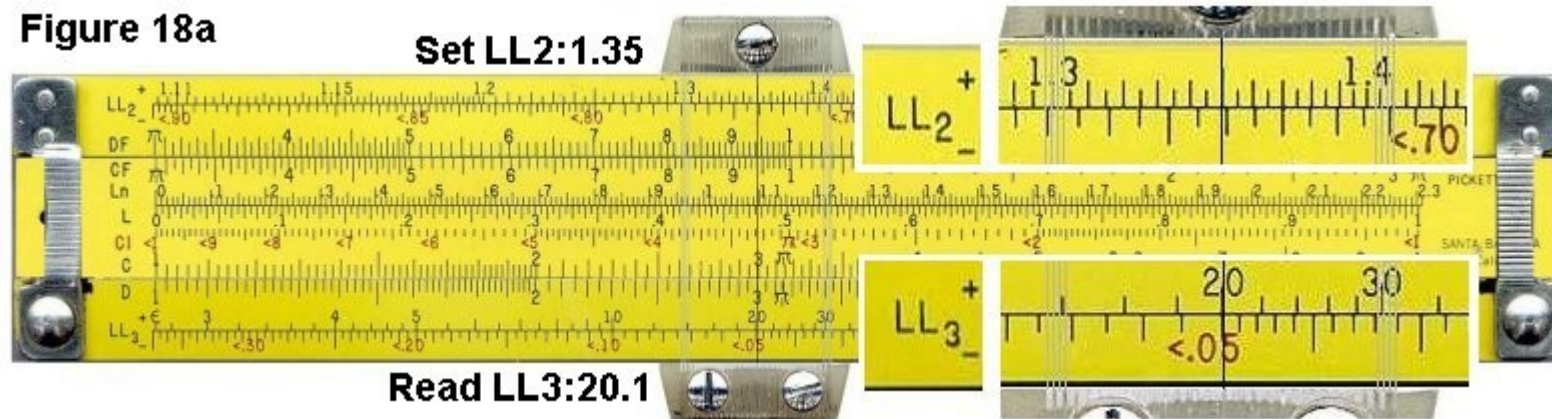
Figure 18a

Example 18b: calculate 1.04^{100} (uses LL1 and LL3 scales)

- Set the cursor over 1.04 on the LL1 scale.
- Flip the SR over
  (on some advanced SR's the LL0, LL1, LL2 and LL3 will be on the same side)
- The cursor is at 50.5 on the LL3 scale.
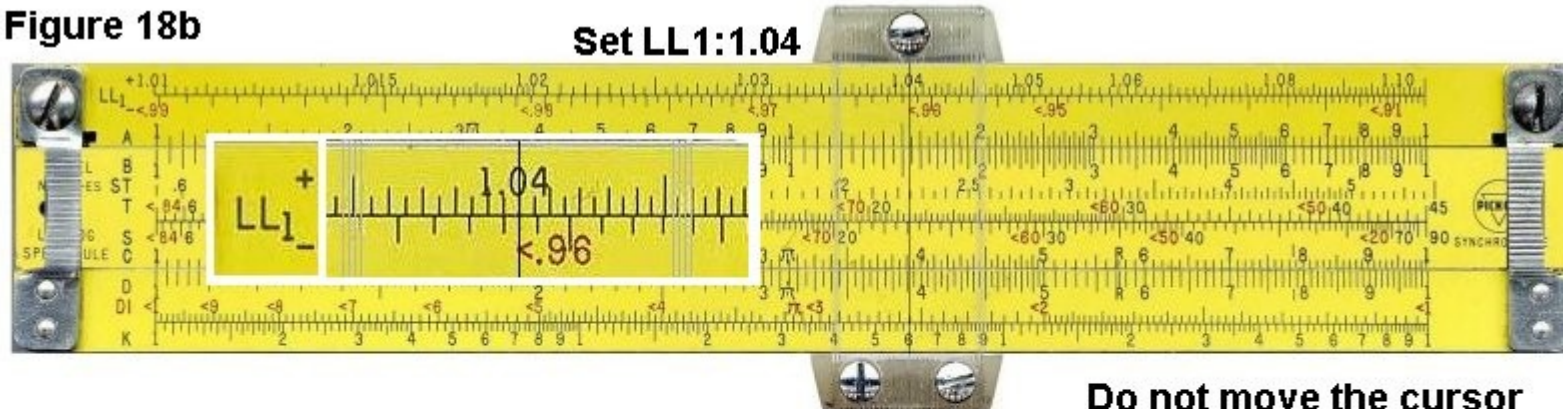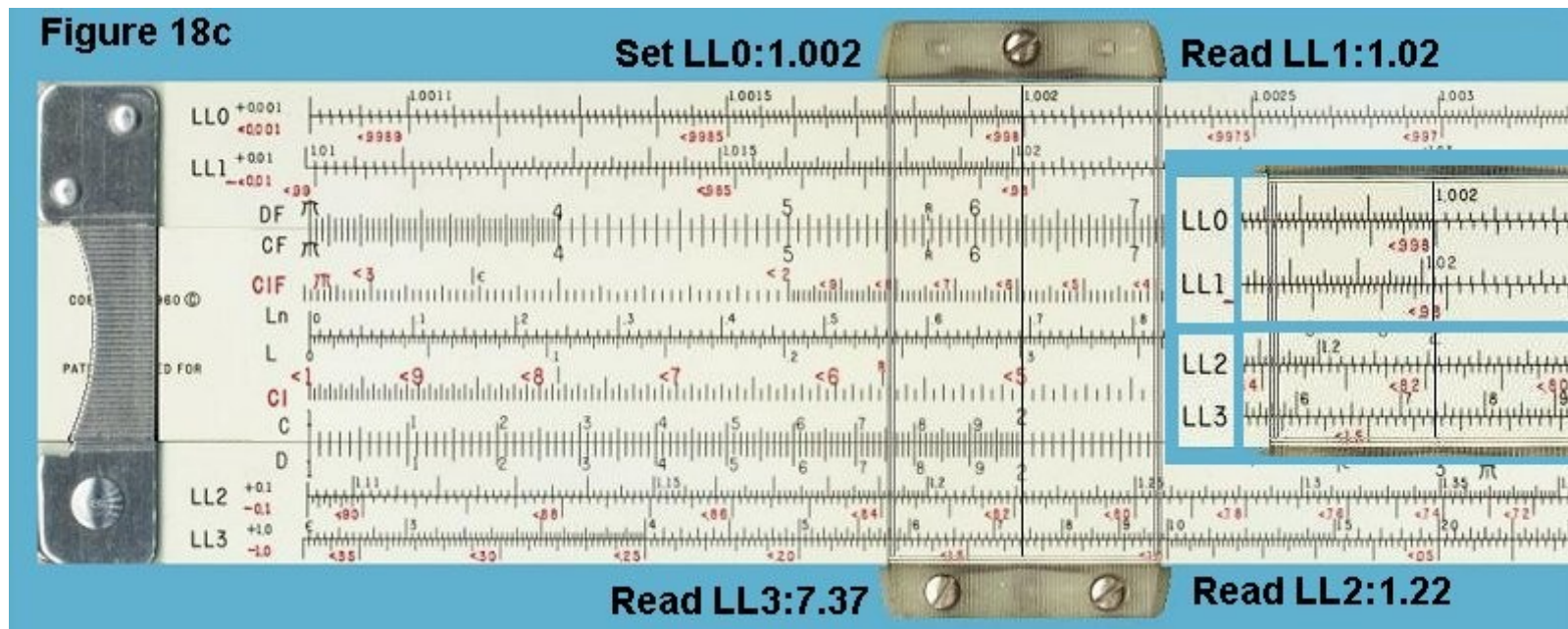

Figure 18b

Set LL1:1.04

Do not move the cursor while flipping the SR over!

Figure 18b Flipped

Read LL3:50.5

Example 18c: calculate 1.002^{1000} (uses LL0 and LL3 scales)

- Set the cursor over 1.002 on the LL0 scale.
- The cursor is on 7.4 on the LL3 scale. This is the correct answer.

Figure 18c

Example 18d: calculate sequential powers of ten of 1.002 (uses LL0, LL1, LL2 and LL3 scales)

- Set the cursor to 1.002 on the LL0 scale. This the same as 1.002^1
- On LL1, the cursor is at 1.002^{10}, or 1.020
- On LL2, the cursor is at 1.002^{100}, or 1.22.
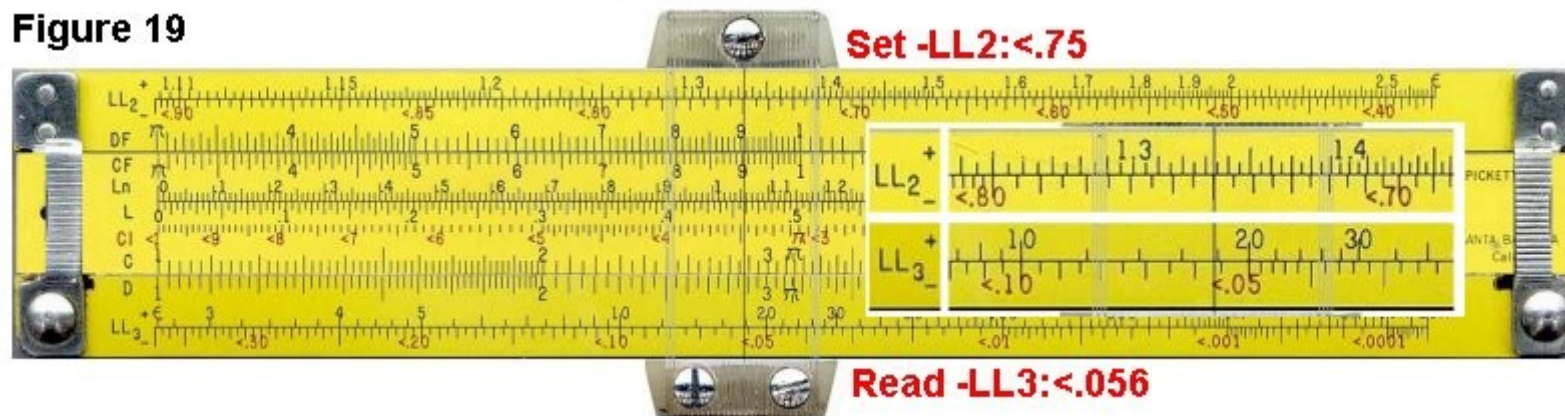- On LL3, the cursor is at 1.002^{1000}, or 7.37.

Figure 18c
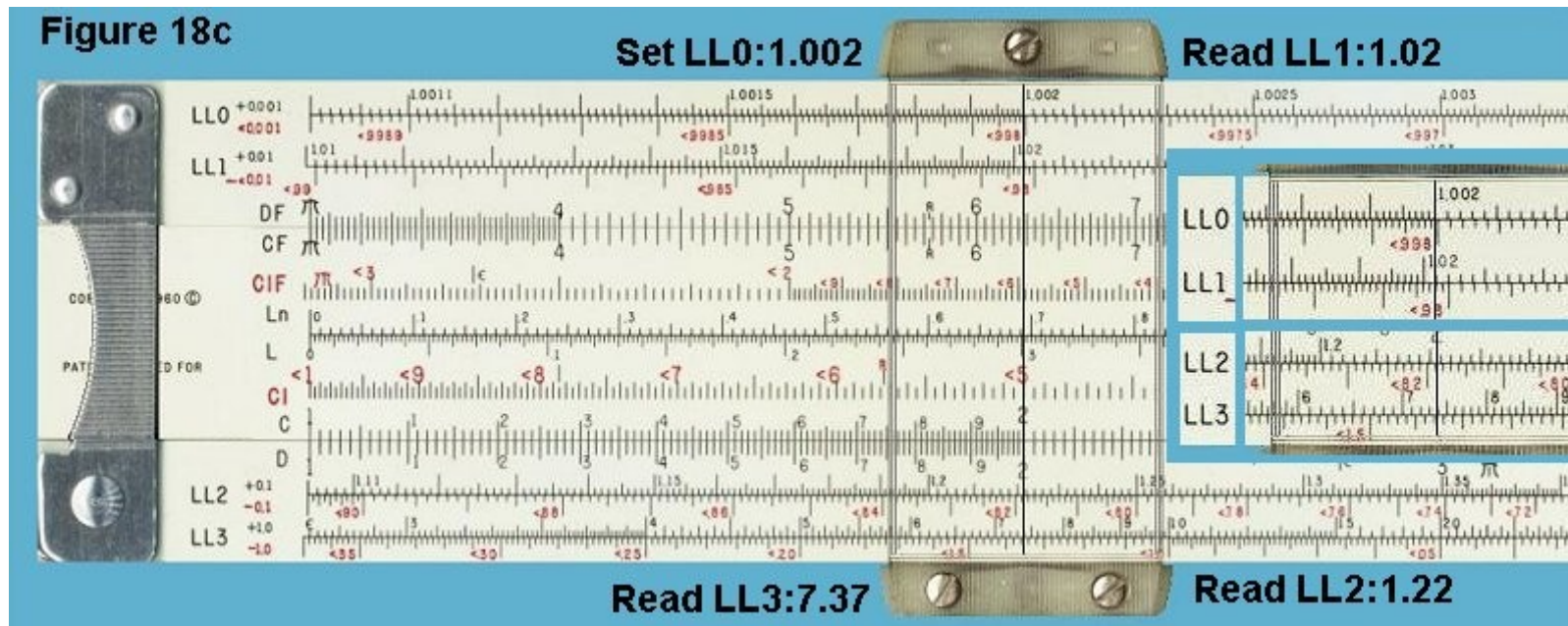
19. Raising a Number to Powers of 10 (N<1)

The reciprocals of the LL scales are the -LL scales. They work the same way, but you have to make sure that you look for the answer on a -LL scale. They are RED scales so they increase in value from right to left.

Example 19: calculate 0.75¹⁰ (uses -LL2 and -LL3 scales)
- Move the cursor to <0.75 on the -LL2 scale.
- The cursor is at <0.056 on the -LL3 scale. This is the correct answer.

Figure 19

20. Raising a Number to Powers of -10   (N<1), N^{-10} or $1/N^{10}$

The reciprocals of the LL scales are the -LL scales. They work the same way, but you have to make sure that you look for the answer on a -LL scale.

Example 20: calculate 1.175^{-10} (uses LL2 and -LL3 scales)
- Set the cursor hairline to 1.175 on the LL2 scale.
- The hairline is over 5 on the LL3 scale. This is 1.175^{10}
- The cursor is also over .2 on the -LL3 scale.

This is the reciprocal of 1.175^{-10} or $1/1.175^{10}$ and is the correct answer.

Figure 20

Set Hairline to LL2:1.75

Read -LL3:2
Note: -LL3 = 1/+LL3
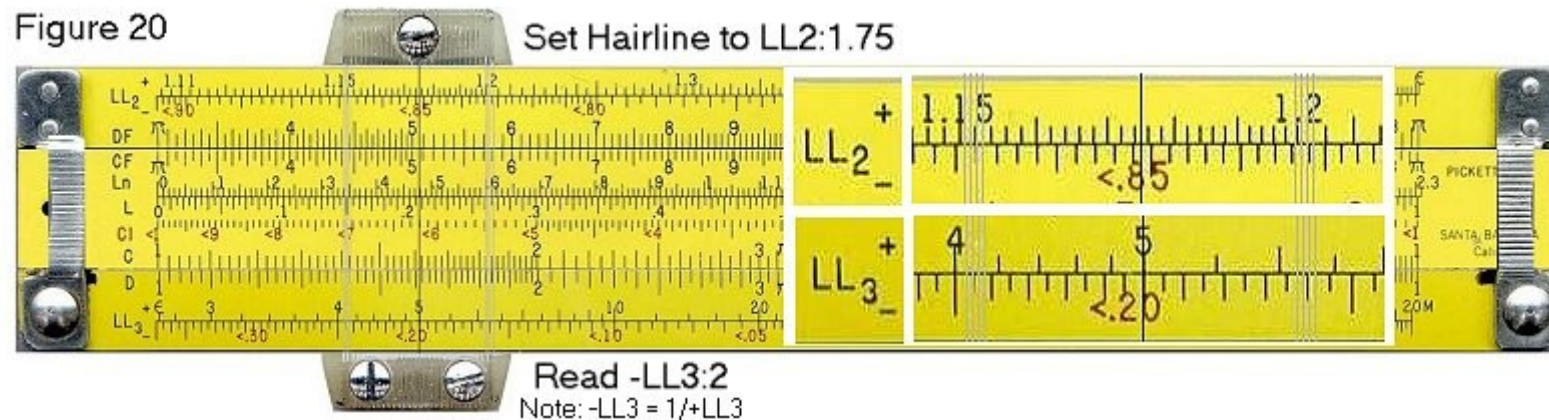
21. Finding the 10th Root (N>1)

As you've seen in the previous examples, to raise a number to the 10th power, you simply look at the adjacent number on the next highest LL scale. To find a tenth root, you look at the adjacent number on the next lowest LL scale. Remember also that finding the tenth root is the same as raising a number to the power of 0.1.

Example 21: calculate $^{10}\sqrt{5}$, or $5^{0.1}$ (uses LL2 and LL3 scales)
- Set the cursor over 5 on the LL3 scale.
- The cursor is now at 1.175 on the LL2 scale. This is the correct answer.

Figure 21   Read LL2:1.175

Set LL3:5.0
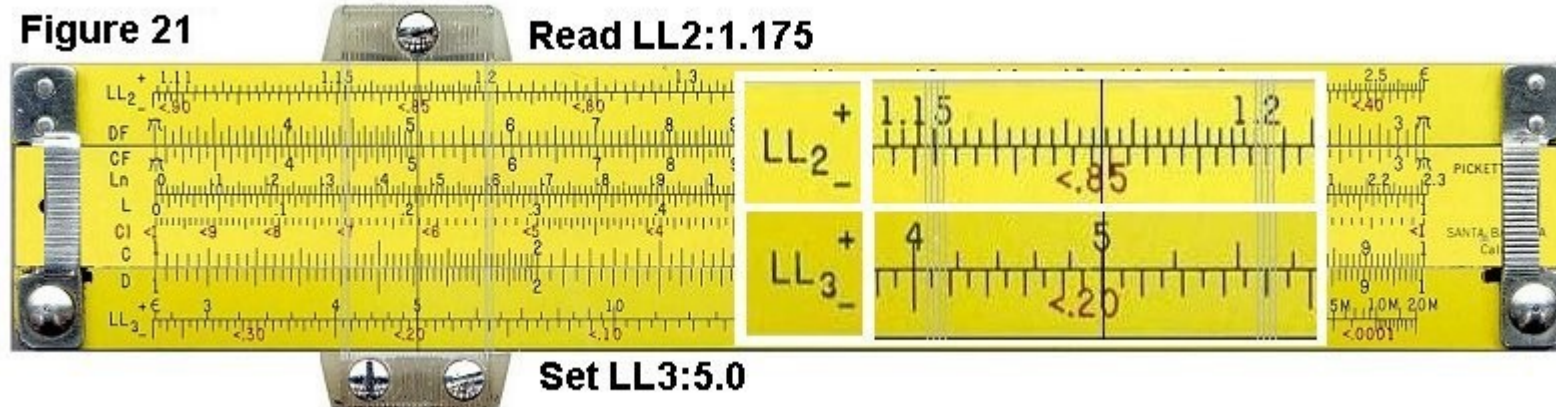
22. Finding the 10th Root (N<1)

Example: calculate $^{100}\sqrt{0.15}$, or $0.15^{0.01}$ (uses -LL3 and -LL1 scale)

- Set the cursor to 0.15 on the -LL3 scale.
- Flip the SR to the other side to read the LL1 scale.
- The cursor reads 0.9812 on the -LL1 scale. This is the correct answer.
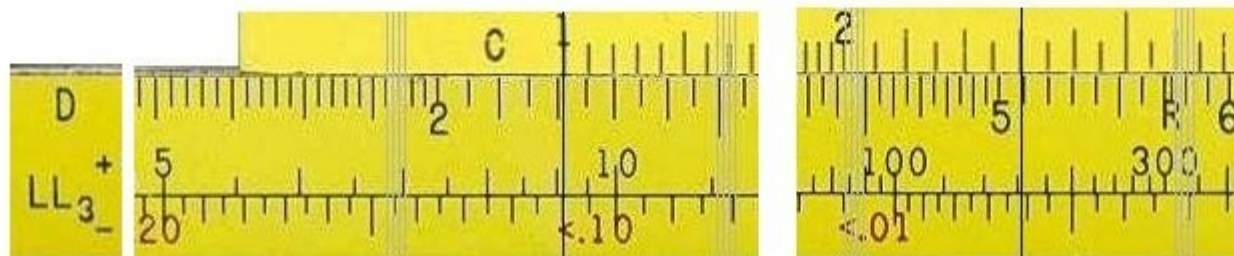

Figure 22
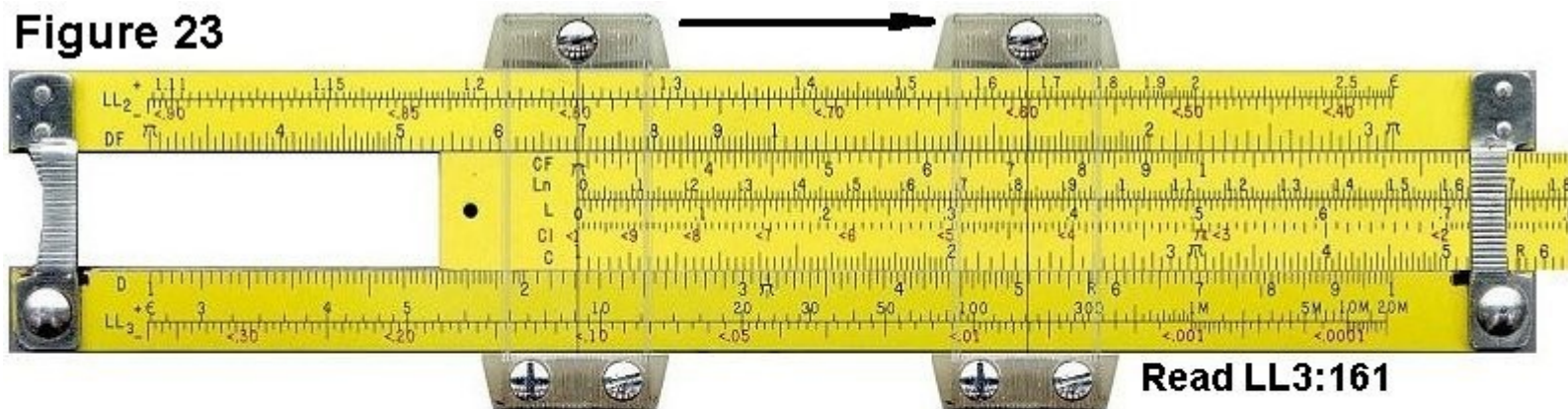
Set -LL3:<.15

Read -LL1:<.9812
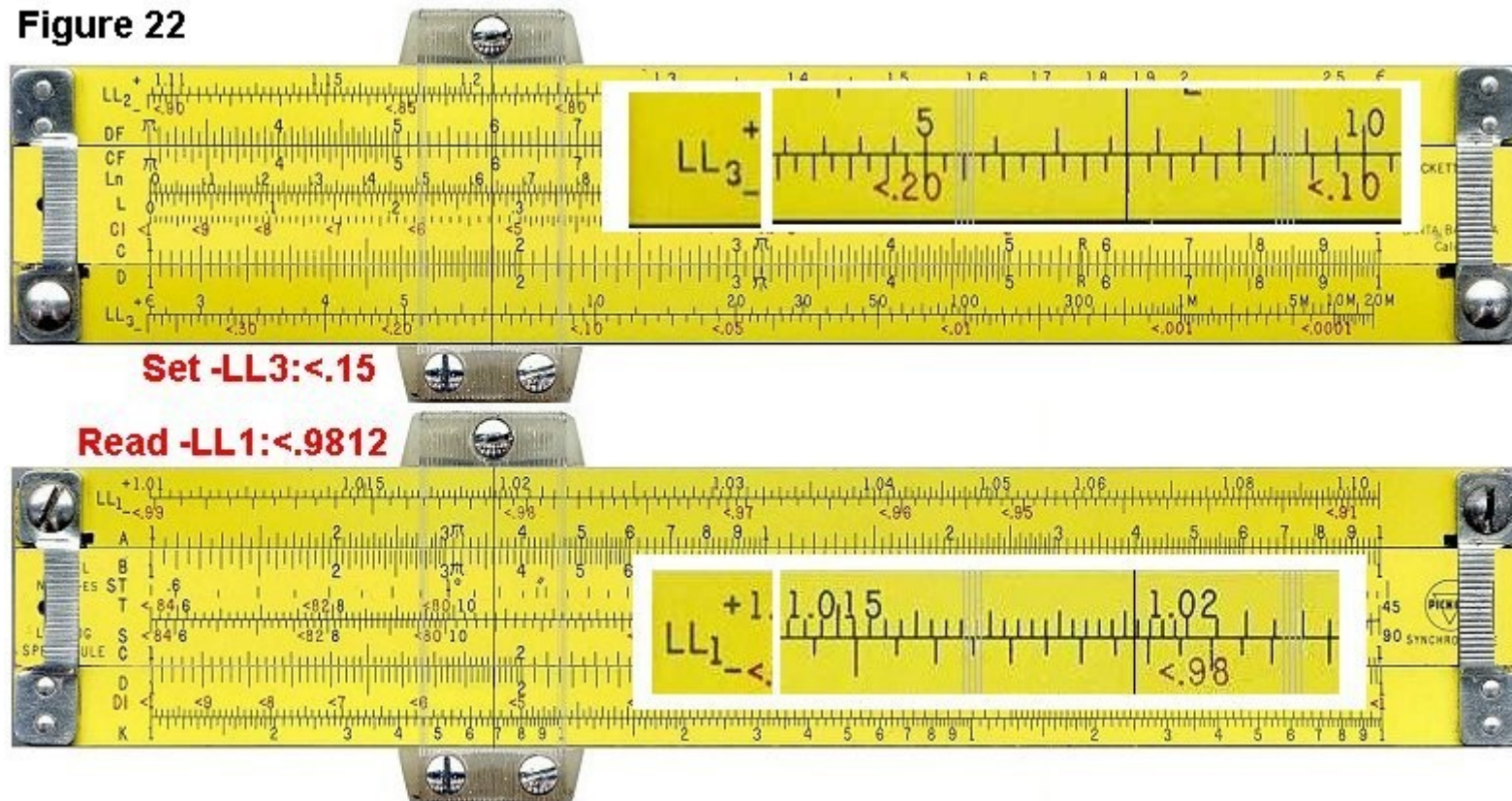
23. Arbitrary Powers (Staying on Same LL Scale)

Occasionally, depending on the numbers, it is possible to calculate a power without switching scales.

Example: calculate $9.1^{2.3}$ (uses LL3 scale)

- Set the cursor hairline to 9.1 on the LL3 scale.
- Slide the leftmost Index '1' on C to the hairline.
- Move the hairline over 2.3 on the C scale.
- The cursor is now at about 161 on the LL3. This is very close to the correct answer of 160.6. One of the problems with LL scales is that their accuracy diminishes as the numbers increase in value.
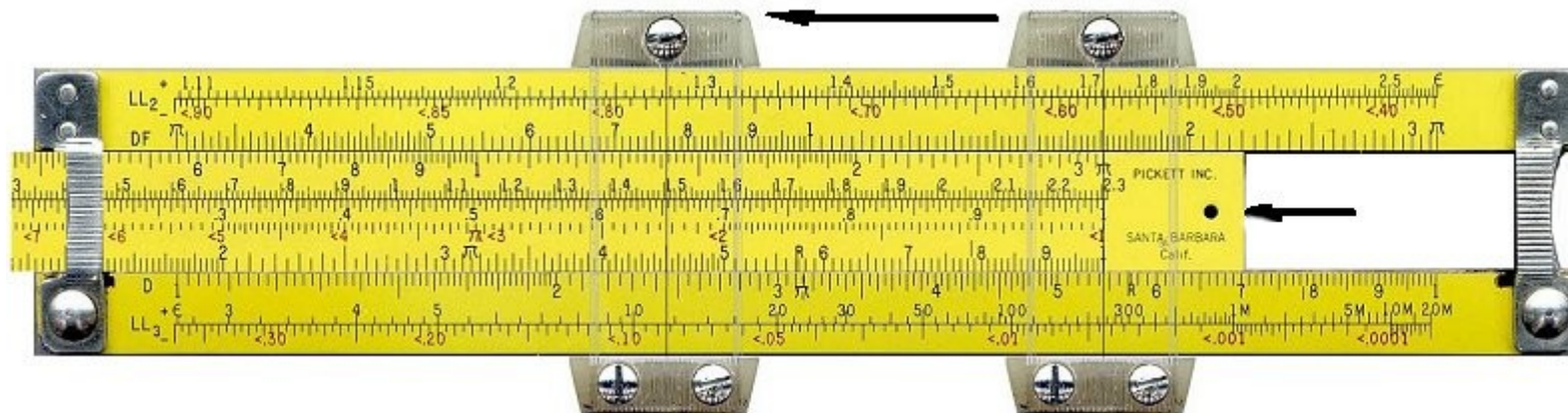

Figure 23

Read LL3:161

Example: calculate 230 $^{0.45}$ (uses LL3 and C scale)

- Set the cursor to 230 on the LL3 scale.
- Since we're raising to a power that's less than 1, we have to go left on the LL scale.
- Slide the right most Index '1' on the C scale to the cursor hairline.
- Move the cursor to 4.5 on the C scale.
- The cursor is now at 11.6 on the LL3 scale. This is close to the correct answer of 11.56.
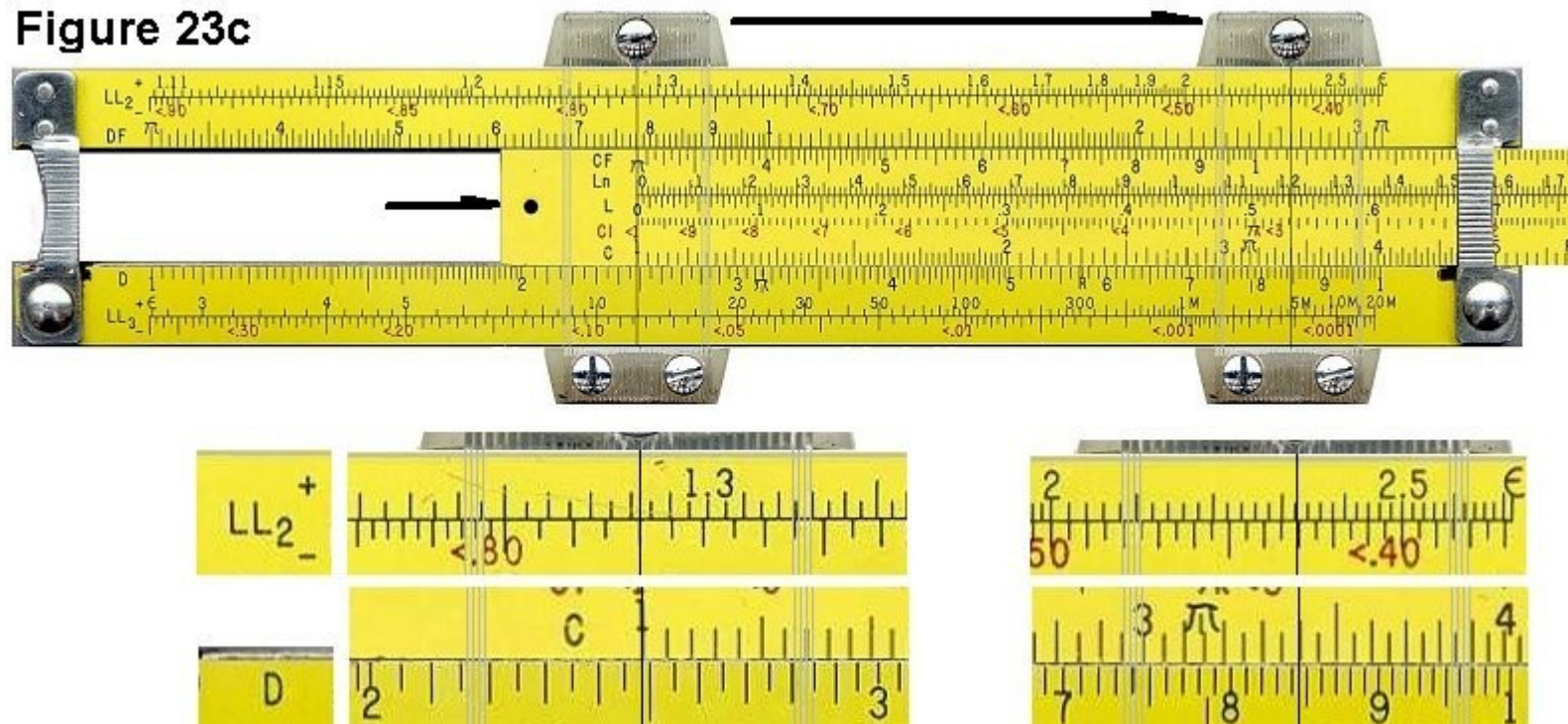
Example: calculate $0.78^{3.4}$ (uses -LL2 and C scale)
- Set the cursor to 0.78 on the -LL2 scale.
- Slide the leftmost Index '1' on the C scale to the cursor hairline.
- Move the cursor to 3.4 on the C scale.
- The cursor is now at 0.43 on the -LL2 scale. This is the correct answer.

Figure 23c

Example: calculate $0.78^{0.45}$ (uses -LL2 and C scale)

- Set the cursor to 0.78 on the -LL2 scale.
- Since we're raising to a power that's less than 1, we have to go left on the LL scale.
- Slide the rightmost Index '1' on the C scale to the cursor hairline.
- Move the cursor to 4.5 on the C scale.
- The cursor is now at 0.894 on the -LL2 scale. This is the correct answer.
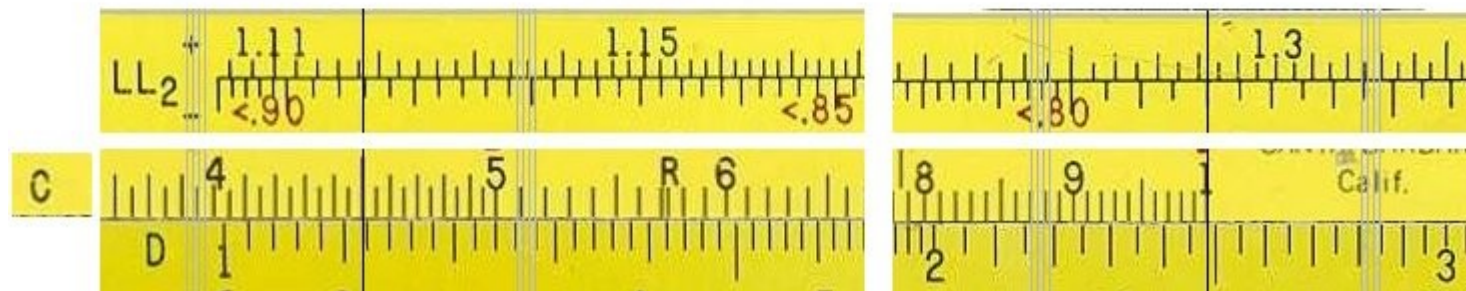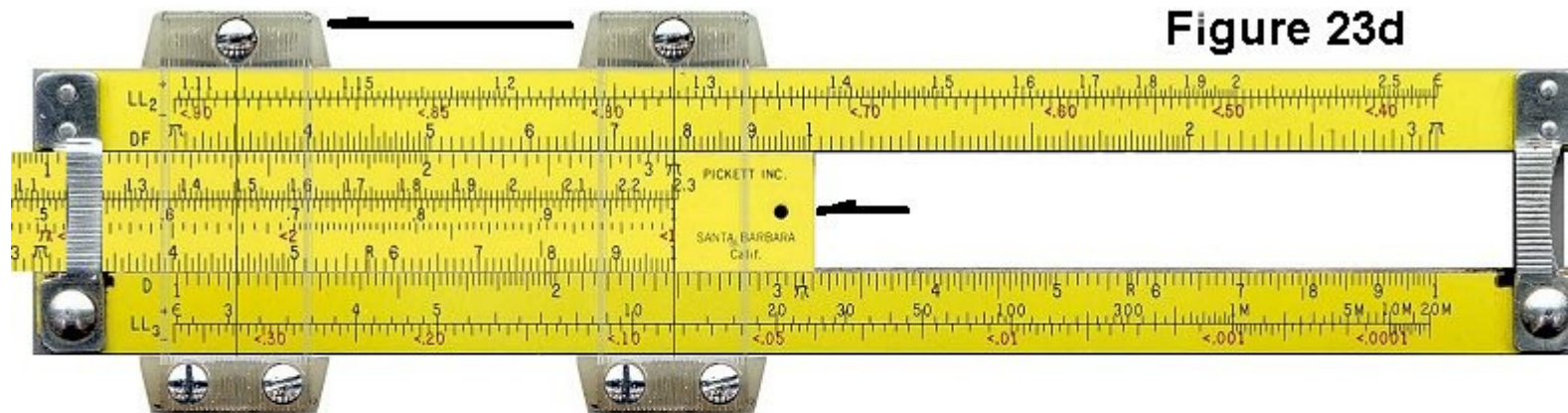

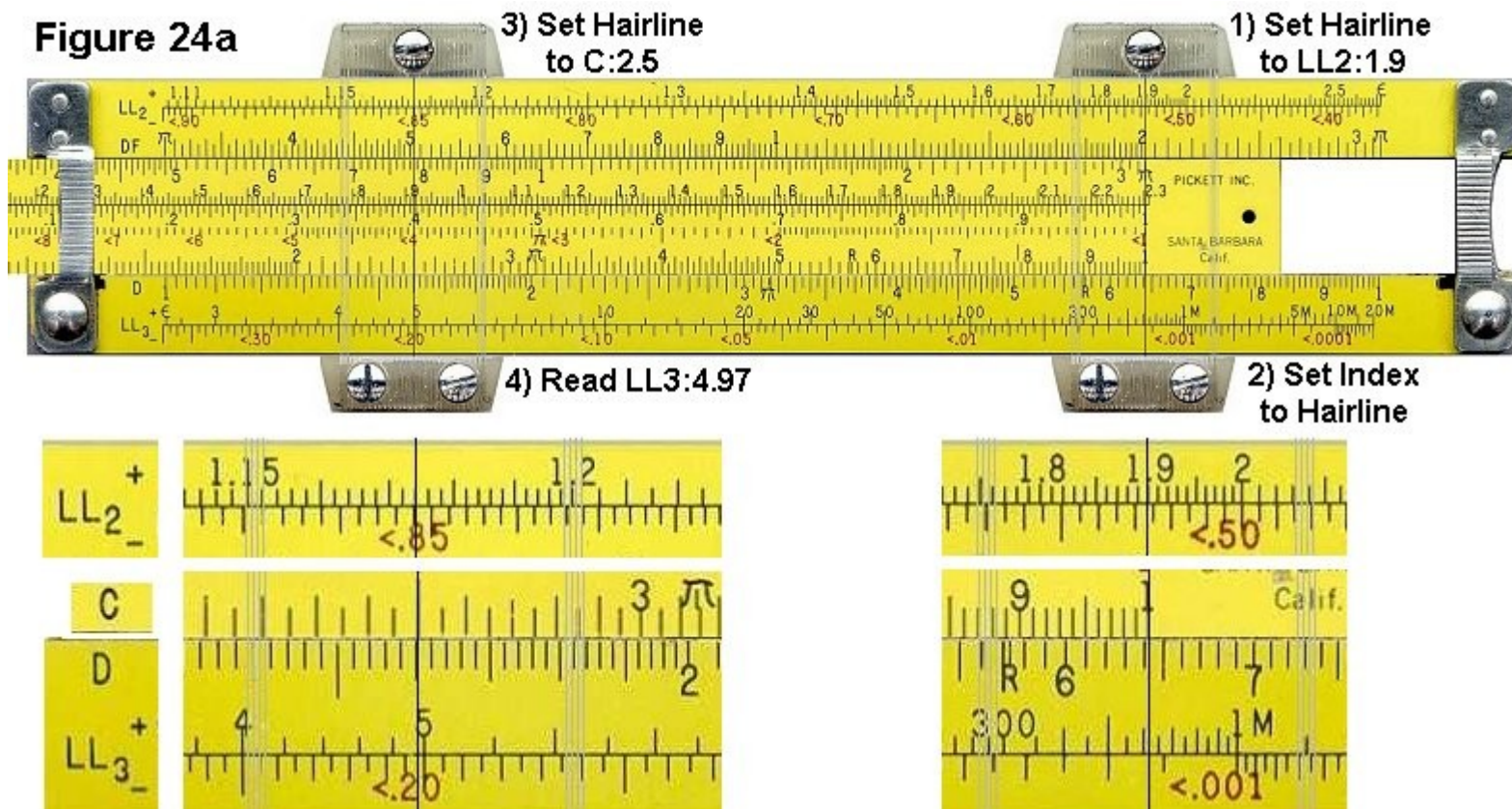Figure 23d

24. Arbitrary Powers (Switching LL Scales)

One of the rules of exponents is that $(A^B)^C$ is equal to $A^{B \times C}$. We can use this fact, along with our knowledge of powers of ten, to calculate arbitrary powers.
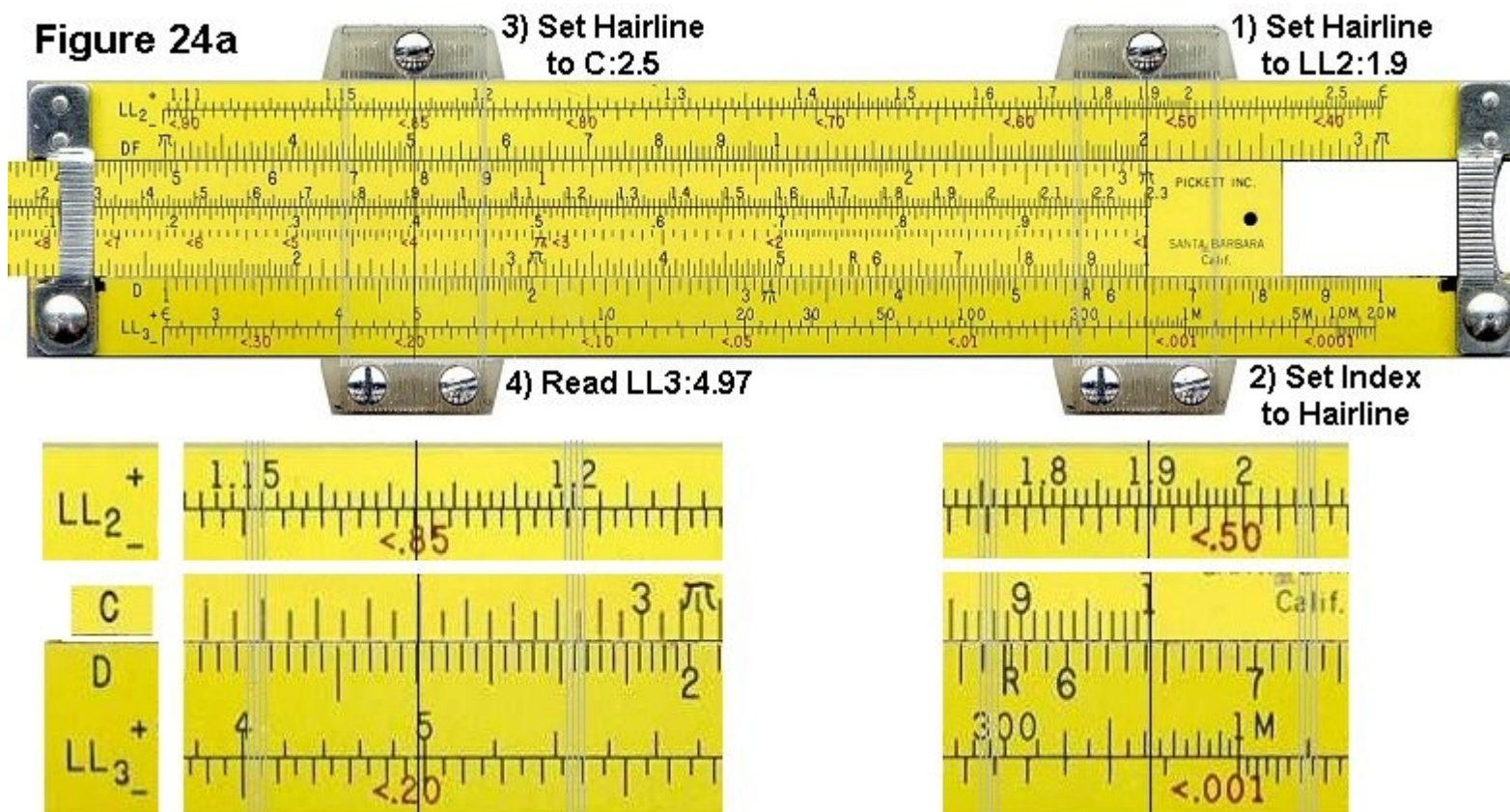
Example: calculate $1.9^{2.5}$ (uses LL2, C and LL3 scales)

- If we try to calculate this the easy way, the power 2.5 is out of range for the scale.

Figure 24a

24. Arbitrary Powers (Switching LL Scales) Cont'd.

- We can reinterpret the problem as:
  Calculate $(1.9^{0.25})^{10}$ Because 0.25 x 10 is 2.5.
- Set the cursor hairline to 1.9 on the LL2 scale.
- Slide the rightmost Index '1' on the C scale to the hairline.
- Shift the cursor hairline to 2.5 on the C scale.
- The hairline is now at $1.9^{0.25}$ on the LL2 scale. Since we want to also raise this to the power of 10, we look "one scale higher" at the LL3 scale.
- The cursor is at 4.97 on the LL3 scale. This is the correct answer.

Figure 24a

3) Set Hairline to C:2.5

1) Set Hairline to LL2:1.9

4) Read LL3:4.97

2) Set Index to Hairline

Example: calculate $12^{0.34}$ (uses LL3, C and LL2 scales)

- Like the previous example, if we try to calculate this the easy way, the power 0.34 is out of range for the scale. We can reinterpret the problem as:
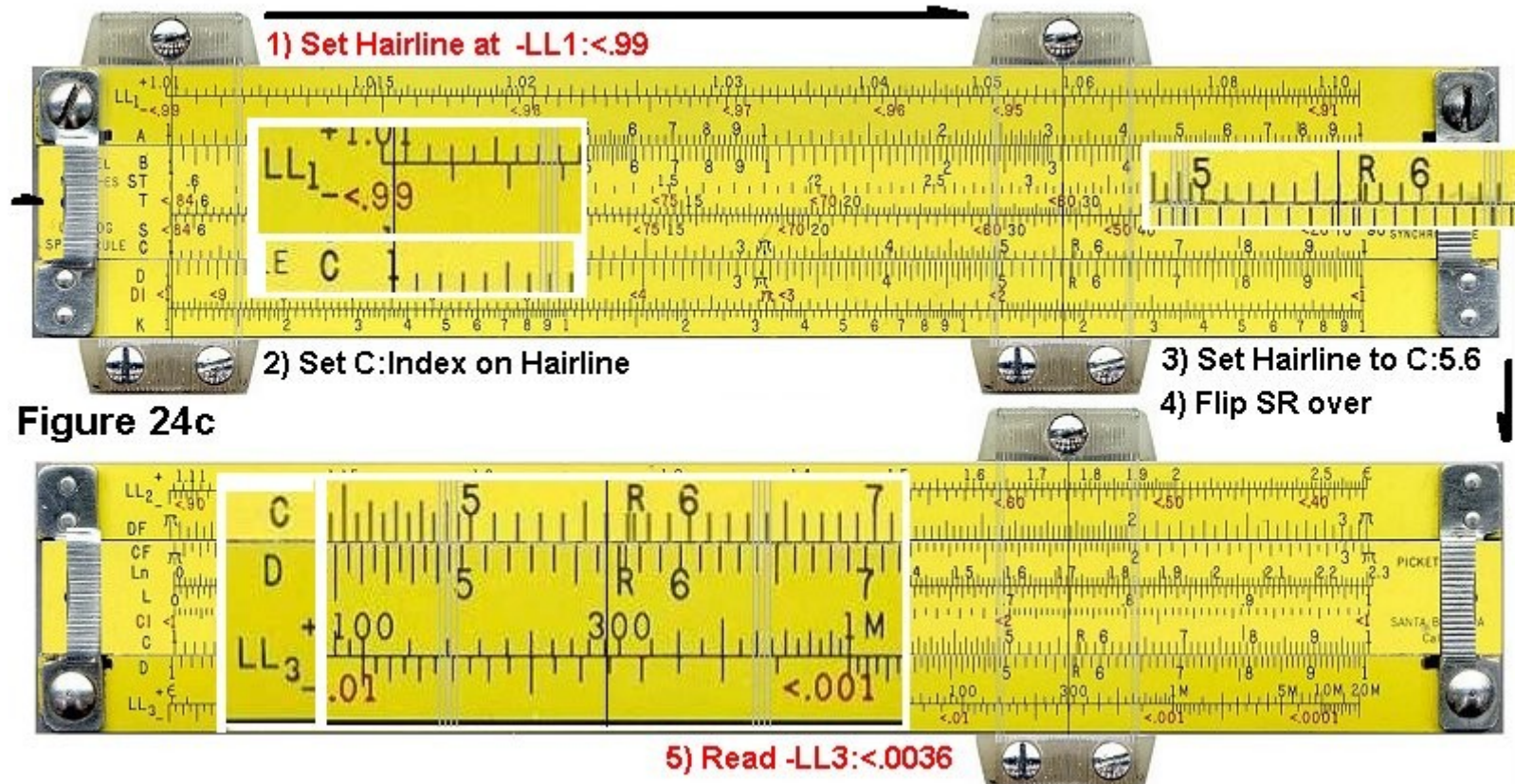
  Calculate $(12^{3.4})^{0.1}$ Because 3.4 x 0.1 is 0.34.

- Move the cursor to 12 on the LL3 scale.

- Slide the left most '1' on the C scale to the cursor.

- Move the cursor to 3.4 on the C scale.

- The cursor is now at $12^{3.4}$ on the LL3 scale, which is about 5000 (which is not the number we're looking for). Since we also want to raise this to the power of 0.1, we look at the LL2 scale.

- The cursor is now at 2.33 on the LL2 scale. This is the correct answer.

Figure 24b

2) Set Index to Hairline

4) Read LL2:2.33

1) Set Hairline to LL3:12

3) Shift Hairline to C:3.4
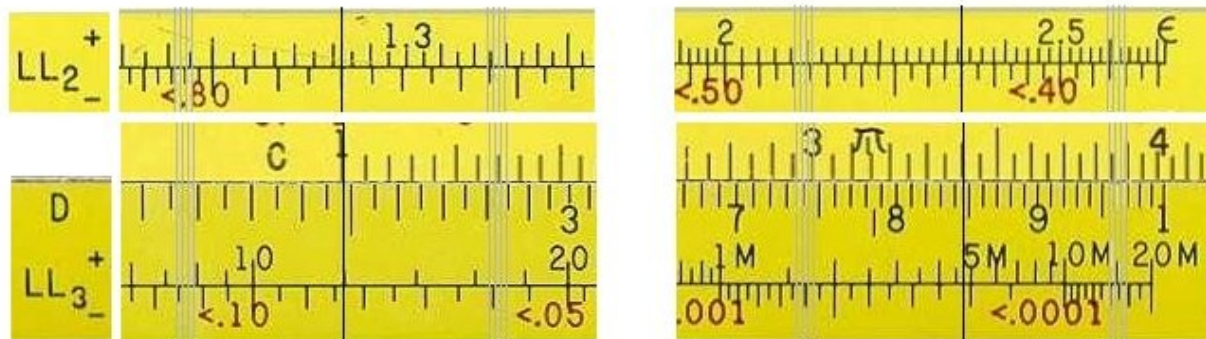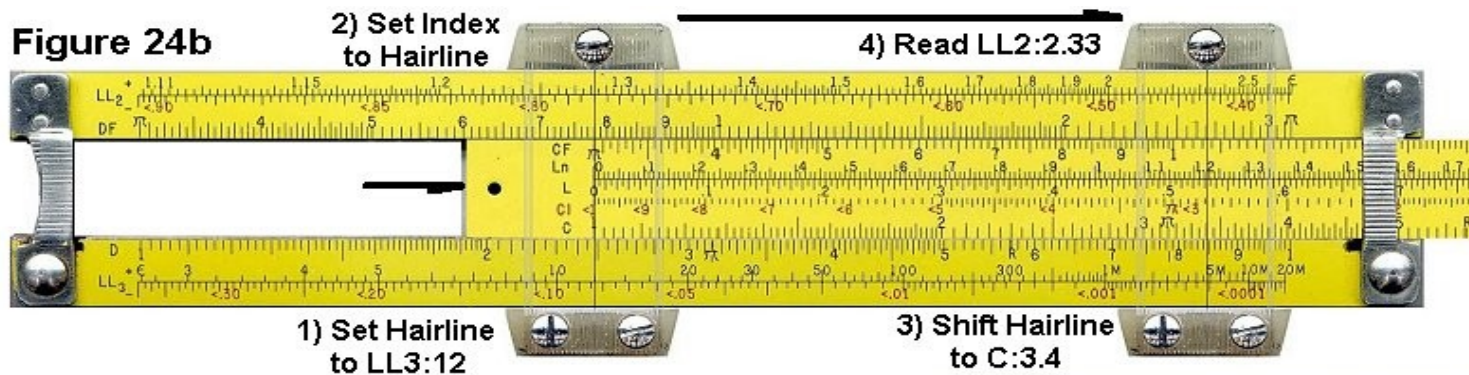
Example: calculate 0.99 ^{560} (uses -LL1, C and -LL3 scales)

- We can reinterpret this problem as:
  Calculate $(0.99^{5.6})^{100}$ Because 5.6 x 100 = 560
- Set the cursor Hairline to <0.99 on the -LL1 scale.
- Shift the leftmost Index '1' on the C scale to the cursor hairline.
- Move the cursor to 5.6 on the C scale.
- The cursor is now at <0.99 $^{5.6}$ = <0.9452 on the -LL1 scale.
- Since we also want to raise this to the power of 100, we look "two scales higher", or the -LL3 scale.
- The cursor is now at <0.0036 on the -LL3 scale. This is the correct answer.

Figure 24c

1) Set Hairline at -LL1:<.99
2) Set C:Index on Hairline
3) Set Hairline to C:5.6
4) Flip SR over
5) Read -LL3:<.0036

25. Log-Log Approximations

In general, LL scales don't handle numbers extremely close to 1, such as 1.001 or 0.999. This is not a problem because there is an accurate approximation for numbers in this range. In general, if you have a very small number 'd', then:

$$(1 + d)\,p = 1 + d\,p$$

Continues on next slide:

Example: calculate 1.00012 ^{34} (uses C and D scales)

- In this case, if we use the approximation $(1 + d)^p = 1 + d\,p$, then:
  d = 0.00012, and
  p = 34

- We must calculate 0.00012 * 34.

- Set the leftmost Index '1' on the C scale to 1.2 on the D scale..

- Set the cursor hairline on 3.4 on the C scale.

- The cursor is now at 4.08 on the D scale.

- We know that the correct answer would be near 0.0001 * 30, or 0.003. Therefore we adjust the decimal point to get a value of 0.00408.

- Add 1 to 0.00408. The result is 1.00408, which is very close to the correct answer of 1.004088.

Figure 25a

1) Set C:Index to D:1.2
2) Set Hairline to C:3.4
3) Read D:4.08
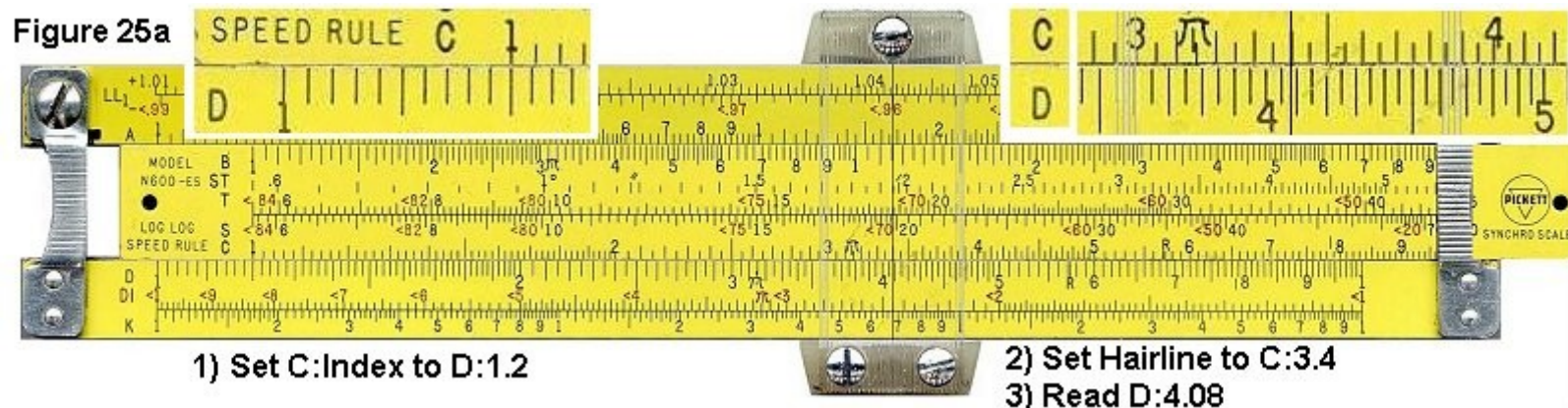
In the beginning, at the time of the great flood, Noah went thru his ark after it landed, and found two small snakes huddled in a corner. Noah looked at these poor specimens - and said "I told you to go forth and multiply - why haven't you?"

The poor snakes looked up at Noah and replied "We can't because we are adders....."

Noah looked a bit perplexed, and then proceeded to tear bits of planking from his ark. He went on to build a beautiful wooden platform. He gathered up the snakes and placed them on the platform, and joyfully told the snakes - "Now go forth and multiply, because even adders can multiply on a log table"

D. Scott MacKenzie, PhD
Metallurgist specializing in Heat Treatment and Quenching

That's it for this seminar!

You may be asked to do a short quiz.

Afterwards, If you were issued a slide rule as part of this class, please return the slide rule in its protective sleeve along with any course materials that you were given.