Name: ________________________________

Lab – Slide Rules and Log Scales

[EER Note: This is a much-shortened version of my lab on this topic. You won't finish, but try to do one of each type of calculation if you can. I'm available to help.]

The logarithmic slide rule was the calculation instrument that sent people to the moon and back. At a time when computers were the size of rooms and ran on tapes and punch cards, the ability to perform complex calculations with a slide rule became essential for scientists and engineers. Functions that could be done on a slide rule included multiplication, division, squaring, cubing, square roots, cube roots, (common) logarithms, and basic trigonometry functions (sine, cosine, and tangent). The performance of all these functions have all been superseded in modern practice by the scientific calculator, but as you may have noted by now, the calculator has a "black box" effect; that is, it doesn't give you much of a feel for what an answer means or whether it is right. Slide rules, by the way they were manipulated, gave users more of an intrinsic feel for how operations were performed. The slide rule consists of nine scales of varying size and rate – some are linear, while others are logarithmic.

Part 1 of 2: Calculations (done in class)

In this lab, you will use the slide rule to perform some calculations. **You may not use any other means of calculation!**

You will be given a brief explanation of how to perform a given type of calculation, and then will be asked to calculate a few problems of each type.

For each calculation, you'll need to compare a number from one scale with a number on another scale. The scales will be referred to by the one- or two-letter abbreviation on the slide rule we've given you, but be aware that if you found another slide rule they might use a different letter for the same scale. (For real fun, go on the internet and buy an old Soviet slide rule, with labels in Russian).

On these scales, the numbers do not go to "double digits", except for those designed for angles in degrees. For scales not in degrees, once you get to "10", it appears as "1", and the scale repeats itself. You need to remember that each successive "1" has an additional "0" at the end compared to whatever you started with (it is 10 times as much as the previous "1"). The same applies to successive values of any other number that is less than 10.

In most cases, to get a precise value, you will need to read the measurement on the scale very carefully. On classic slide rules they provide a clear "cursor" with a "hairline" that can be read across all the scales. In your case, you'll need to line up the scales with a straight edge of some sort, from a piece of paper, for example. Your calculation accuracy will depend on the right angle of that edge with respect to the two scales in question, so be careful.

No calculators – use the slide rule for your calculations whenever possible!

Multiplication

To multiply two numbers, you will use the A and B scales. Select the number you wish to multiply on the B scale, and slide that scale leftward until it lines up exactly with the first 1 (on the left side) of the A scale. Now find the number on the A scale that you wish to multiply *by*, and look down at the B scale to find your answer. The easy way to test it is to line up B-2 with A-1, then pick any number on A and look down. You're multiplying by 2 (which I hope you can do in your head). *Note: this can also work backwards. You can slide the B scale to the right, use the 1 on the B scale, and line it up with the A number you wish to multiply by, find your other number on B, and look upward for an answer*. *<u>This can also be done using the C and D scales! (That only works for products that come out less than 10).</u>* Example: 2 * 6. Slide B until 2 lines up with 1 on the A scale. Find 6 on the A scale. Look down. You will be at "1.2", but you'll note you're on the second set of scales for B, so this is not from 1 to 2, it's from 10 to 20 (so the 1.2 becomes 12).

Problems

$$2.3 \times 4.1 = \_\_\_\_\_\_\_\_$$

Division

This is backwards from how you just did multiplication. First, think of your division problem (for terminology purposes) as a fraction (i.e., a numerator divided by a denominator). In this case, the easiest way is to slide the B scale to the right. Find your numerator on the A scale, find your denominator on the B scale, and line them up. Look left, and wherever B=1, A should be your answer. However, remember the note about single digit numbers! If your numerator or your denominator has to be multiplied or divided by 10 one or more times, you're supposed to be able to move the decimal point the appropriate number of spaces! Once again, the example here is to line up 6 on the A with 2 on the B. Look across to where B is 1, and look up. A at that point is 3. *Again, remember, for division of numbers that are less than 10, you can use the C and D scales with finer precision!*

Problems

$$5.4 \div 2.2 = \_\_\_\_\_\_\_\_$$

Squaring

To find the square of a number, we will be using the D and A scales. *No sliding is needed.* Find your number to be squared on the D scale. Look up (you'll need a straight edge) on the A scale, and you'll find the square (remembering the decimal place issue!) The example here is that if you look at 6 on the D scale, you'll find 3.6 on the A scale. But since it's the *second* 3.6, this means it's actually 36. **Please note that if you have included a factor of 10 or more in your original number that's not in the scale, that factor must also be squared!**

Problems

$$2.6^2 = \_\_\_\_\_\_$$

Square Roots

This is inverse operation of the previous operation, of course. Find the number you want the root of on the A scale, and look down at D for your square root. Remember, as above, to pay attention to your proper decimal place/digit.

Problems

$$\sqrt{22} = \_\_\_\_\_\_\_\_$$

Cubing

This is similar to the squaring operation performed before, but instead of comparing D to A, you compare D to K. Line up 3 on the D scale, and look up to K, and you find 2.7 on the second scale (which is 27 when you correct the scale).

Problems

$$2.8^3 = \_\_\_\_\_\_\_\_\_$$

Cube Roots

As with square roots and squares, this is the inverse of cubing. Find the number on your K scale of which you wish to take the cube root. Look down at the D scale, and there is your answer. Go to 6.4 on the second scale (64), and looking down, your cube root on the D scale is 4.

Problems

$$\sqrt[3]{25} = \_\_\_\_\_\_\_\_\_$$

Reciprocals

The reciprocal, simply, is $1/x$. To perform this calculation, you will use the C and CI scales. No sliding is needed. *However, this is tricky because one scale is going to need a decimal point!* They do not provide one because they don't know which number (x, or $1/x$) is the one you have in mind. You won't need to slide anything. Find your number on the C scale; the reciprocal is on the CI scale… almost. If you are using a number less than 1 ($0<|x|<1$), you will imply a decimal point before your original number, but your answer will not have one. If your original number is above 1, you will need to imply that the numbers on the CI scale have a decimal point in front of them. For every additional zero – that is, for every place you move that decimal point over – you must move your answer over by 10 as well. This one, as I said, is tricky until you get the hang of it. So find 2 on the C scale. Look up at CI and you'll see it lines up as 5. Since your original number is 2, you must imply a decimal point before your answer, so it is 0.5 (which is correct). If the original number had been 0.2, the CI would not need a decimal point, and the answer would be 5 (again, that is correct; the reciprocal of 1/5 is 5). This one calls for a lot of looking back! The reciprocal of a positive number greater than 1 is less than 1, and the reciprocal of a positive number less than 1 is greater than 1. If your answer doesn't reflect that, you need to rethink.

Problems

$$\frac{1}{4.65} = \_\_\_\_\_\_\_\_$$

Trigonometry

The slide rule can give you the sine, cosine, tangent, cotangent, arcsine, arccosine, arctangent, and arccotangent of any known angle in degrees. To find the sine of an angle in degrees, locate the angle on the S scale. The sine will be found on the D scale. The cosine does not have its own scale, but uses the lighter shaded numbers under the sine scale (so if you want a cosine, find the angle on the lighter version of the scale, and look up to the D scale). Note that the D scale goes up to 1 as a maximum here! So if you look at 30 on the S scale, and look up to the D scale, you'll find the value is "5". But since the max value is 1, the answer is actually 0.5.

Problems (all angles are in degrees)

$$\sin 16.4° = \_\_\_\_\_\_\_\_\_$$

$$\tan^{-1} 0.5 = \_\_\_\_\_\_\_\_\_\_$$

Common Logarithms

The last use of this tool, and the most relevant for our purposes (indeed, the reason we had these made) is the common logarithm (that is, a logarithm to the base of 10). As this lab follows the first of the class sessions on logs in general, I will remind you that all a logarithm asks is to what power would you have to raise a base (in this case, 10) in order to reach another number that is given. To find common logs, you will use the D and L scales, and no sliding is required. Find the number of which you are taking a logarithm on scale D. Look down to scale L and you find your response. So for log(7), you look at the number 7 on the D scale, look down, and you'll find the answer is 0.845. (This is an approximation. The actual answer is much longer.)

But wait – this scale only lets you go up to 10. What if you have to take the log of a number larger than 10? This requires that you learn the rules for manipulating logs. They are as follows, and will be quite useful in this course:

$$\log ab = \log a + \log b$$

$$\log(\frac{a}{b}) = \log a - \log b$$

$$\log a^b = b \log a$$

$$\log_a b = \frac{\log_n b}{\log_n a} \ (note\ that\ n\ could\ be\ 10)$$

So if you use these rules, you should be able to reduce any log until it is a number less than 10 (it may not be a whole number).

Problems (if no base appears, assume base 10, always)

$$\log 4.55 = \_\_\_\_\_\_\_\_\_$$

$$\log 175.4 = \_\_\_\_\_\_\_\_\_$$

$$\log_4 9.2 = \_\_\_\_\_\_\_\_\_$$

And lastly (figure out how to do this on your own)….

$$10^{0.635} = \_\_\_\_\_\_\_\_\_$$

Part 2 of 2: Creating Your Own Slide Rule from Log Scales

Working alone or with one partner, you are to construct a multiplication/division slide rule (these correspond to scales A and B on the slide rule you used in class). Each of your scales – which you should label, although you don't necessarily need to call them A/B – should be a logarithmic scale from 1 to 1(0), with two full cycles on each scale. That is, each scale will go from 1 to 1(0) to 1(00), although the zeroes will be implied only, for reasons you hopefully understand from the first part of the lab.

You will calculate the distance from one mark to the next using the logarithm function on your calculator. It may take you a few tries to do it right, so this is why you have two whole sheets of graph paper when you only really need two strips. I will give you the hint to use the *smallest* division as your guide, to make sure you can do this. Make the length of a grid square equal to a unit (call it whatever you like), and figure out how many of those should correspond to each "tick mark" on your scale (and remember each mark is going to be different on a logarithmic scale). Much like with the slide rules we gave you, more open space on your scale gives you room to put smaller divisions with a reasonable degree of precision!

When your scales are complete, make sure you test your model! I won't give you any complicated problems, so just pick some simple arithmetic here. Multiply some easy numbers together and see if it works. Try several numbers to be sure! Make sure to do division too.

Submission (due in 5 minutes – but the students get a week)

Your submission is your scales, your calculations, and your explanation of how you made them. I'm aware that you can simply look up a slide rule template online and copy it, and this is why you need to show me your work, including all calculations for where your "marks" went on the scale.

Make sure your name is on it, of course.

[EER Note: This handout, as noted much earlier, is just a much-shortened version of my lab for this topic. Clearly I cannot expect you to complete all this work in this time, nor is it the point; I simply want you to see the merit in the activity, and wonder whether your students a) could do it, and b) could benefit from the attempt.]