



WEIRD MULTIPLICATION



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THINKING MATHEMATIS!
Volume 1: Arithmetic = Gateway to All

available at www.jamestanton.com.

CONTENTS:

Weird Multiplication Newsletter	Page 2
Commentary	Page 4
Finger Multiplication	Page 9
Russian Multiplication	Page 10



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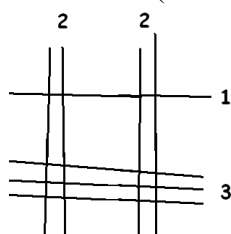
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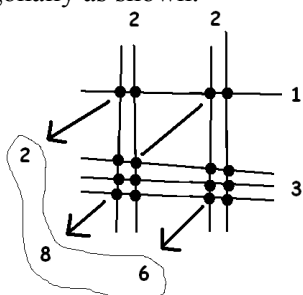
SEPTEMBER 2007

PUZZLER: WEIRD MULTIPLICATION

Here's an unusual means for performing long multiplication. To compute 22×13 , for example, draw two sets of vertical lines, the left set containing two lines and the right set two lines (for the digits in 22) and two sets of horizontal lines, the upper set containing one line and the lower set three (for the digits in 13).

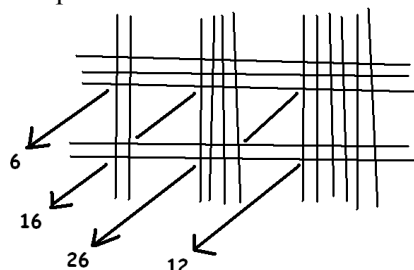


There are four sets of intersection points. Count the number of intersections in each and add the results diagonally as shown:



The answer 286 appears.

There is one caveat as illustrated by the computation 246×32 :



Although the answer 6 thousands, 16 hundreds, 26 tens, and 12 ones is absolutely correct, one needs to carry digits and translate this into 7,872.

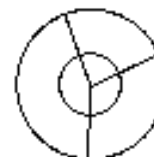
- Compute 131×122 via this method.
- Compute 54×1332 via this method.
- How best should one compute 102×30054 via this method?
- Why does the method work?

A TINY TIDBIT:

Putting on one's shoes and then one's socks does not produce the same result as first putting on one's socks and then one's shoes. These two operations are not commutative.

In mathematics, multiplication is said to be commutative, meaning that $a \times b$ produces the same result as $b \times a$ for all numbers a and b . Is this obviously true? It might not be given the following graphical model for multiplication:

To compute 2×3 , for instance, first draw two concentric circles to model the first number in the problem, 2, and three radii to model the second number, 3.



The number of separate pieces one sees in the diagram - in this case 6 - is the answer to the multiplication problem.

Is it at all obvious that drawing three concentric circles and two radii will produce the same number of pieces?

Suppose one draws 77 circles and 43 radii. Can we be sure that drawing 43 circles and 77 radii

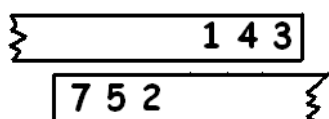
yields an equivalent number of pieces?

Is the commutativity of multiplication a belief or a fact?

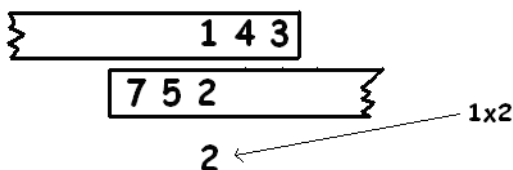
ANOTHER TIDBIT:

Here's another way to compute a multiplication problem; 341×752 , for instance.

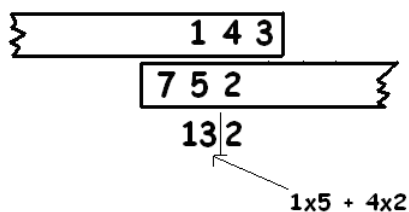
Write each number on a strip of paper, reversing one of the numbers. Start with the reversed number on the top strip to the right of the second number.



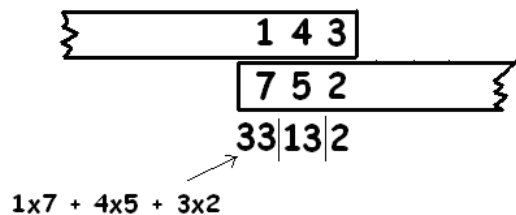
Slide the top number to the left until a first set of digits align. Multiply them and write their product underneath.



Slide one more place to the left and multiply the digits that are aligned. Write their sum underneath.

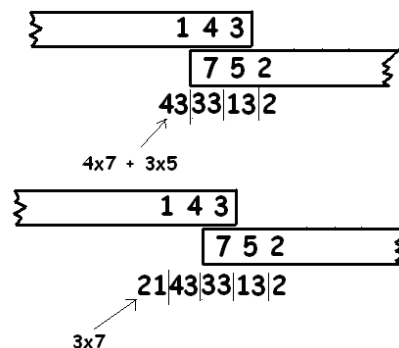


Continue this process:



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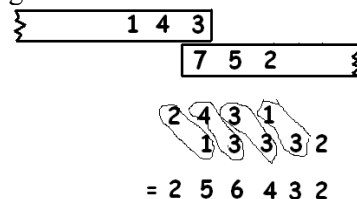


The answer to 341×752 is:

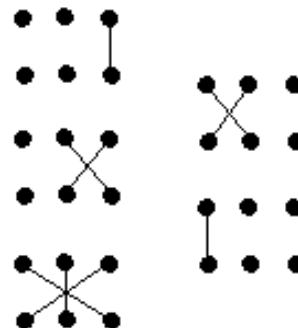
$$21 \mid 43 \mid 33 \mid 13 \mid 2$$

namely, 21 ten-thousands, 43 thousands, 33 hundreds, 13 tens and 2 ones. After carrying digits this translates to the number 256,432.

COMMENT: Some people may prefer to carry digits as they conduct this procedure and write something akin to:



ANOTHER PUZZLER: Vedic mathematics taught in India (and established in 1911 by Jagadguru Swami Bharati Krishna Tirthaji Maharaj) has students compute the multiplication of two three-digit numbers as follows:



What do you think this sequence of diagrams means?

RESEARCH CORNER: Invent your own method of conducting long multiplication.



II: COMMENTARY

I have found the content of this newsletter to be a big hit with folks teaching middle-school students and, in general, a delight for students of all ages to ponder upon. Along with "finger multiplication" and "Russian multiplication" presented below, these techniques truly demonstrate the joy to be had engaging in intellectual play.

The multiplication methods outlined invite us to reexamine the long-multiplication algorithm we teach our young students. Consider, for example, the computation 83×27 . Students are taught to write something of the ilk:

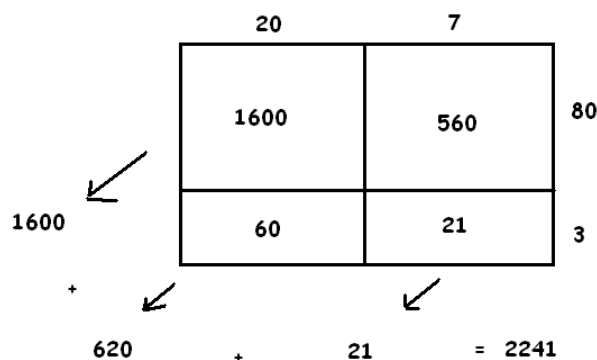
$$\begin{array}{r}
 83 \\
 \times 27 \\
 \hline
 21 \\
 560 \\
 60 \\
 \hline
 1600 \\
 \hline
 2241
 \end{array}$$

Mathematicians recognize this as an exercise in "expanding brackets:"

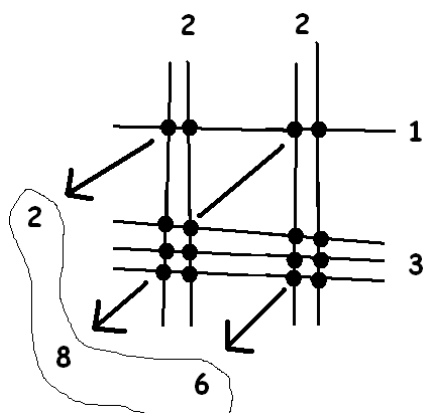
$$83 \times 27 = (80 + 3)(20 + 7) = 1600 + 60 + 560 + 21$$

(Select one term from each set of parentheses, multiply, and repeat. Add together all possible combinations that can arise in this way.)

Young students might be taught to associate an "area model" with multiplication, in which case, expanding brackets is equivalent to dividing a rectangle into computationally simpler pieces.

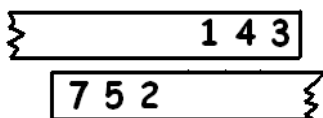


It is now easy to see that the lines method is just the area model of multiplication in disguise (since the count of intersection points matches the multiplication of the single digit numbers).



$$22 \times 13 = 286$$

The strip method is a clever geometric tracking of the individual multiplications that occur in a long multiplication problem (with place-value keeping track of the powers of ten for us):

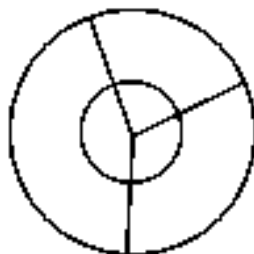


And the Vedic technique is a memorization device for the standard algorithm.

CHALLENGE: Think about these. Be sure to understand why these two techniques really are just alternative ways of presenting our familiar long multiplication algorithm.

Circle/Radius Math

It is not too hard to see that drawing a common radii for b circles yields ab pieces. (One radius produces b pieces and each radius inserted thereafter adds an additional b segments.)



Thus, "circle/radius math" is ordinary multiplication in disguise. (Is it? What happens if one or both of a or b is zero?) As ordinary multiplication is taken to be commutative, this multiplication must be commutative too. Without thinking through the arithmetic, this can be a surprise.

PEDAGOGICAL COMMENT: The Role of the Area Model for Multiplication

Mathematicians recognize that the area model for multiplication has its theoretical limitations—what is the area of a $\sqrt{3}$ -by- $\frac{15}{97}$ rectangle, for example?—but it does justify the axioms we care to work with when we define the properties we like believe of numbers. Pedagogically, it certainly seems to be an appropriate and intuitively accurate place for beginning understanding and investigation.

For example, if we allow for negative numbers in our considerations and consider rectangles with negative side-lengths (young students absolutely delight in "breaking the rules" in this way), then we can help justify many confusing features of the arithmetic we choose to believe. My favorite is tackling the issue of why the negative times negative should be positive.

In the world of counting numbers, it seems natural to say that 7×3 represents "seven groups of three" and so equals 21. In the same way, $7 \times (-3)$ represents "seven groups of negative three" and equals -21 . It is difficult to interpret $(-7) \times 3$ in this way, but if we choose to extend the commutativity law to this realm, then we can say that this is the same as "three groups of negative seven" and so again is -21 . Up to this point, I find that students (and teachers!) feel at ease and willing to say that all is fine. The kicker comes in trying to properly understand $(-7) \times (-3)$.

Let's do this by computing 23×17 multiple ways. Here is the standard way:

	30	7
20	600	140
3	90	21

$$23 \times 37 = 600 + 90 + 140 + 21 = 851$$

Let's be sneaky and compute the same product, allowing ourselves the freedom to play with negative quantities. In the first diagram we choose to represent 23 as $30 - 7$, in the second we write 37 as $40 - 3$. Both again, of course, yield the answer 851.

	30	7
30	900	210
-7	-210	-49

$$23 \times 37 = 900 - 210 + 210 - 49 = 851$$

	40	-3
20	800	-60
3	120	-9

$$23 \times 37 = 800 + 120 - 60 - 9 = 851$$

Now let's write 23 as $30 - 7$ and 37 as $40 - 3$ together at the same time. This represents the same computation and the answer must still be 851.

	40	-3
30	1200	-90
-7	-280	??

$$23 \times 37 = 1200 - 280 - 90 + ?? = 851$$

We see that we have no choice but to set $(-7) \times (-3)$ equal to $+21$.



III: FINGER MULTIPLICATION

Don't memorize your multiplication tables. Let your fingers do the work! If you are comfortable with multiples of two, three, four, and five, then there is an easy way to compute product values in the six- through ten times tables. First encode numbers this way:

A closed fist represents "five" and any finger raised on that hand adds "one" to that value.

Thus a hand with two fingers raised, for example, represents "seven" and a hand with three fingers raised represents "eight." To multiply two numbers between five and ten, do the following:

- 1. Encode the two numbers, one on each hand, and count "ten" for each finger raised.*
- 2. Count the number of unraised fingers on each hand and multiply together the two counts.*
- 3. Add the results of steps one and two. This is the desired product.*

For example, "seven times eight" is represented as two raised fingers on the left hand, three on the right hand. There are five raised fingers in all, yielding the number "50" for step one. The left hand has three lowered fingers and the right, two. We compute: $3 \times 2 = 6$. Thus the desired product is $50 + 6 = 56$.

Similarly, "nine times seven" is computed as $60 + 1 \times 3 = 63$, and "nine times nine" as $80 + 1 \times 1 = 81$. Notice that one is never required to multiply two numbers greater than five!

COMMENT: Type "TANTON FINGER" on www.youtube.com to see a video of this!

FINGERS AND TOES: One can compute higher products using the same method! For example, with fingers and toes, one interprets 17×18 as "seven raised fingers" and "eight raised toes." This time we count each raised digit as "twenty" (we have twenty digits fingers and toes in all!) yielding: $17 \times 18 = 20 \times 15 + 3 \times 2 = 306$!

QUESTION: Why does finger multiplication work? Why does finger/toe multiplication work?

QUESTION: Martians have six fingers on each of two hands. Describe their version of the finger multiplication trick.



IV: RUSSIAN MULTIPLICATION

The following unusual method of multiplication said to have originated in Russia.

1. Head two columns with the numbers you wish to multiply.
2. Progressively halve the numbers in the left column (ignoring remainders) while doubling the figures in the right column. Reduce the left column to one.
3. Delete all rows with an even number in the left and add all the numbers that survive in the right. This sum is the desired product!

$$\begin{array}{r}
 37 \times 23 \\
 \hline
 18 \quad 46 \\
 9 \quad 92 \\
 \hline
 4 \quad 184 \\
 \hline
 2 \quad 368 \\
 \hline
 1 \quad 736 \\
 \hline
 \textcircled{851}
 \end{array}$$

$$37 \times 23 = 851$$

Try computing other products via this approach.

QUESTION: Why does this method work?

(See *THINKING MATHEMATICS: Volume 1* for details.)



FINAL FINAL THOUGHT

This packet is about weird multiplication methods. But have you noticed that the spelling of the word "weird" is itself weird?