

# Early Mathematics - Egypt and Mesopotamia

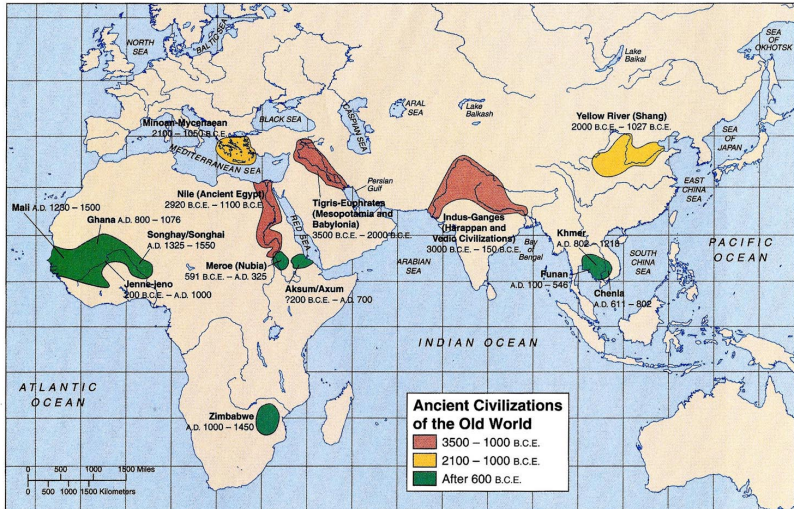
Fall 2025 - R. L. Herman

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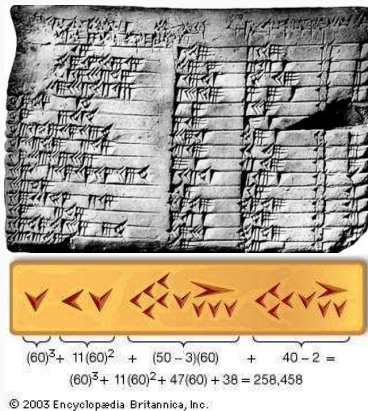
# Maps of Ancient Civilizations

## Ancient Civilizations of the Old World



# Early Civilizations

- Ancient African  $\approx$  20,000 yrs
- Egypt (3150-30 BCE)
- Mesopotamia (3100-539 BCE)
- Indus (3300-1700 BCE)
- Greek (640 BCE-415 CE)
- Chinese (1766 BCE-220 CE)
- Indian Mathematics (500-1200)
- Islamic Mathematics (700-1200)
- Mayan Mathematics (250-900)
- Aztec Empire (c.1345-1521)
- Inca Civilization (1400-1560)



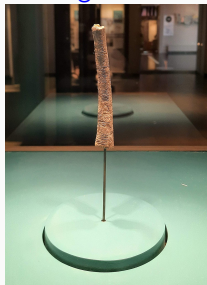
**Figure 1:** Babylonian tablet - Base 60

# Ancient African Mathematics

- Lebombo bone, 43,000-44,200 yrs old. Oldest known mathematical artifact, 29 notches on a baboon's fibula. Found in Border Cave, Lebombo Mountains, Swaziland.
- Ishango bone, 20,000 BCE. Also baboon bone. Ishango, Democratic Republic of Congo. Numerical patterns with differing interpretations.



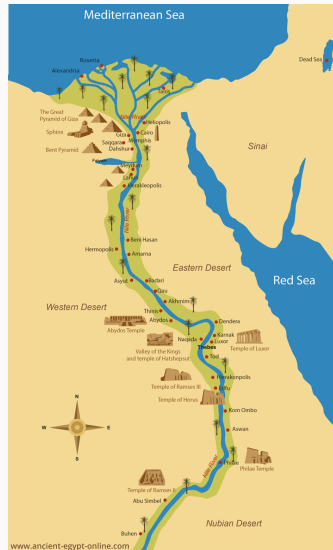
[See Blog and Article](#)



[See Wikipedia.](#)

# Ancient Egypt

- Early Dynastic Period (3150–2686 BCE), writing
- Old Kingdom (2686–2181 BCE) (**Great Pyramid of Giza**)
- 1st Intermediate Period (2181–2055 BCE)
- Middle Kingdom (2055–1650 BCE), **Reisner Papyri** and **Moscow Papyrus**
- 2nd Intermediate Period (1650–1550 BCE), **Rhind Papyrus**
- New Kingdom (1550–1069 BCE)
- 3rd Intermediate Period (1069–664 BCE)
- Late Period (664–332 BCE)



# The Papyri

- Papyri - scrolls.
  - Rhind Papyrus, 1650 BCE.
  - Moscow Papyrus, 1850 BCE.
  - Reisner Papyrus, 1950 BCE.
- Reisner Papyrus
  - Dr. G.A. Reisner .
  - 1901–04 - southern Egypt.
  - 4 scrolls.
  - Mostly accounts.
- Egyptian Arithmetic.
  - Base-10.
  - hieroglyphic and hieratic numerals.
  - integers, fractions.
  - surveying, building.
  - areas, volumes.

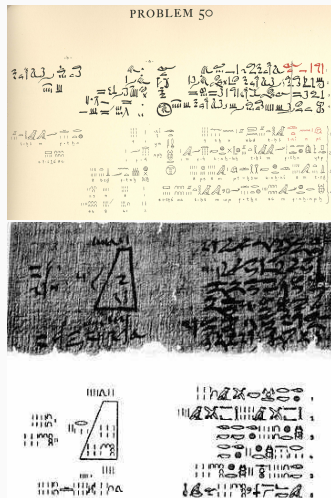
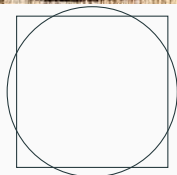
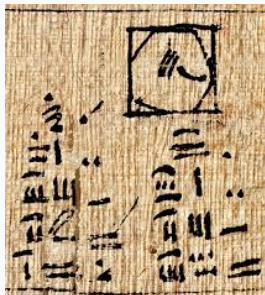


Figure 2: Papyri

# The Rhind Papyrus

- Found in Thebes.
- Purchased 1858, by A. Henry Rhind.
- Size: 18'  $\times$  13''.
- Red and black ink.
- Geometry.
  - Areas, Volumes.
  - Ratios of sides of right triangles.
- Measures - grain.
  - 1 hekat  $\approx 29,224 \text{ in}^3 \geq \frac{1}{2}$  peck.
  - 1 ro =  $\frac{1}{320}$  hekat.
- Areas of Circles - 48, 50.

$$A = \left(\frac{8}{9}D\right)^2 = \frac{256}{81}r^2 \approx 3.16049r^2.$$



$$A_{\text{circle}} = A_{\text{square}} - \frac{1}{9}A_{\text{square}}$$

**Figure 3:** Problem 48

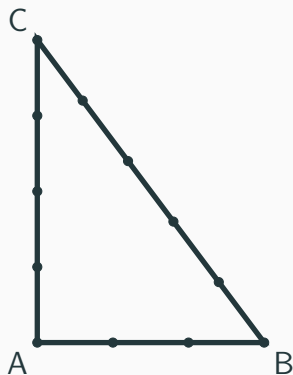
# Pythagorean Triples

- Pythagorean Theorem.
- Triples  $(a, b, c)$ ,

$$a^2 + b^2 = c^2.$$

Examples:

- 3-4-5.
- 5-12-13.
- Used to Measure Perimeters.
- Knotted Ropes.
  - Loop with 12 knots.
- Other Units:
  - Finger - 1.9 cm.
  - Palm = 4 fingers - 7.5 cm.
  - Cubit = 7 palms - 52.3 cm.







# Rhind Papyrus - Problem 50

## Problem 50

tp n ir-t ḥt dbn n ḥt-w<sup>1</sup> 9 pty rḥt · f m ḥt  
*Example of making a field round of khet 9. What is the amount of it in area?*

ḥb · ḥr · k ḡ · f m 1 ḏt m 8 ir-ḥr · k wḥ-tp m 8 sp 8 ḥpr · ḥr · f m 64  
*Take away thou 1/6 of it, namely, 1; the remainder is : 8. Make thou the multiplication : 8 times 8; becomes it : 64;*

rḥt · f pw m ḥt 60<sup>2</sup> ṣt<sup>3</sup> · t 4  
*the amount of it, this is, in area, 60 setat 4.*

ir-t my ḥpr  
*The doing as it occurs:*

1 9  
 ḡ · f 1.  
*of it*

ḥ[b] ḥnt · f ḏt 8  
*Take away from it; the remainder is 8.*

1	8
2	16
4	32
\ 8	64

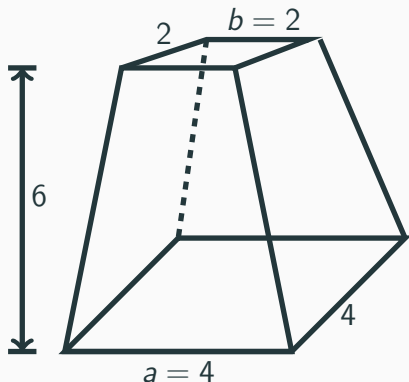
rḥt · f m ḥt 60<sup>2</sup> ṣt<sup>3</sup> · t 4  
*The amount of it in area: 60 setat 4.*

<sup>1</sup> The w suggested by the plural strokes has been omitted on the plate. The same omission occurs on the figure in Problem 51, and in Problem 52, line 2.

<sup>2</sup> The scribe has by mistake written here either the number 60 or the special form for 6 used in Problem 48 in writing 6 *setat*. He may have had in his mind the fact that he was actually dealing with 60 *setat* (which, however, would not properly be written in this way), and he had written the abstract number 60 a moment before at the end of the multiplication, or, remembering that 60 *setat* is written with the numeral 6, he did write 6, but used the special sign instead of the ordinary numeral.

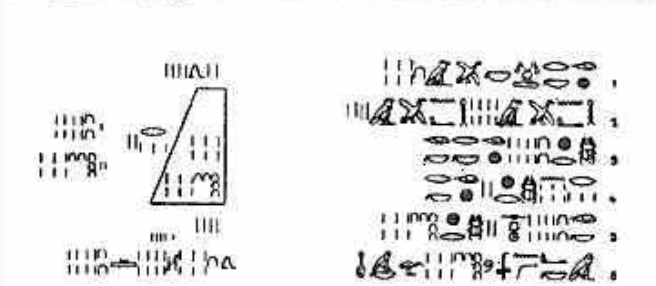
# Moscow Papyrus

- From around 1850 BCE.
- Golenishchev bought in 1892 or 1893 in Thebes.
- Housed in Moscow.
- 25 Problems.
- [https://en.wikipedia.org/wiki/Moscow\\_Mathematical\\_Papyrus](https://en.wikipedia.org/wiki/Moscow_Mathematical_Papyrus)
- See Problem 14:
  - Frustrum of a Pyramid



$$V = \frac{h}{3} (a^2 + ab + b^2)$$

# Moscow Papyrus - Problem 14 - Frustrum of Pyramid





# Mesopotamia (2100 BCE) - Tigris and Euphrates Region

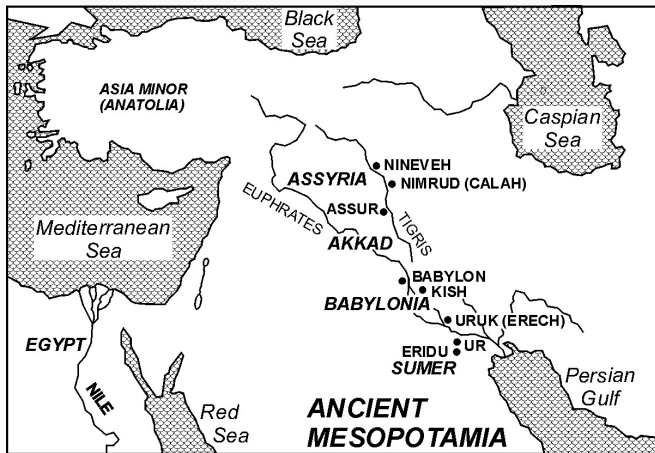


Figure 4: Tigris and Euphrates Rivers

# Babylonian and Sumerian Mathematics

- More Advanced.
- Clay Tablets.
- Base 60 Arithmetic.
- Notation:  $13_{60} = 1.3 = 1/3$ .
- Some use commas: 1,3.
- Examples:

$$1/3 = 1(60) + 3 = 63$$

$$1/59 = 1(60) + 59 = 119$$

$$2/49 = 2(60) + 49 = 169$$

$$3/31/49 = 3(60^2) + 31(60) + 49$$

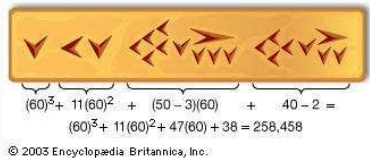


Figure 5: Babylonian tablet - Base 60

# Sexagesimal Operations (Base 60)

- Ambiguities:
  - No 0's.
  - No decimal points.
- Special fractions:
  - $8.25_{10} = 8/15 = 8\frac{15}{60}$
  - $8.5_{10} = 8/30 = 8\frac{30}{60}$
  - $8.75_{10} = 8/45 = 8\frac{45}{60}$
- Addition, subtraction, multiplication.

Addition:

$$\begin{array}{r} 14/28/31 \\ +3/35/45 \\ \hline = 18/4/16. \end{array}$$

Multiplication -

$$ab = \frac{1}{4} [(a + b)^2 - (a - b)^2].$$

No division! - Use reciprocals:

See [Old Babylonian Multiplication and Reciprocal Tables](#).

# Reciprocal Table

Table of reciprocals  $\bar{x}$  of  $x$ , where  $x\bar{x} = 60^n$ ,  $n = 0, 1, \dots$

$x$	$\bar{x}$	$x$	$\bar{x}$	$x$	$\bar{x}$	$x$	$\bar{x}$
2	0/30	8	7/30	16	3/45	30	2
3	0/20	9	6/40	18	3/20	32	1/52/30
4	0/15	10	6	20	3	36	1/40
5	0/12	12	5	24	2/30	40	1/30
6	0/10	15	4	25	2/24	45	1/20

Divide 8 by 2 :  $8(0/30) = 8 \times \frac{30}{60} = \frac{240}{60} = 4$ , or

$0/30 + 0/30 + 0/30 + 0/30 + 0/30 + 0/30 + 0/30 + 0/30 = 1 + 1 + 1 + 1$ .

Missing reciprocals:  $\frac{1}{7}, \frac{1}{11}, \frac{1}{13}, \frac{1}{17}, \frac{1}{19}, \dots$

# Sumerian Tablet - YBC 7289 - imšukkuḡ, or “hand tablet”

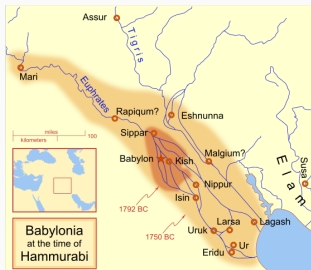
- From southern Iraq, 19th or 18th century BCE.
- Yale Peabody Museum of Natural History, 3D Print.
- Babylonians knew ratio of the side to diagonal in a square,  $1 : \sqrt{2}$ .



$$1/24/51/10 = 1 + \frac{24}{60} + \frac{51}{60^2} + \frac{10}{60^3} \approx 1.414213$$

$$42/25/35 = 42 + \frac{25}{60} + \frac{35}{60^2} \approx 42.426$$

# Plimpton 322 Clay Tablet (in the news in 2017)



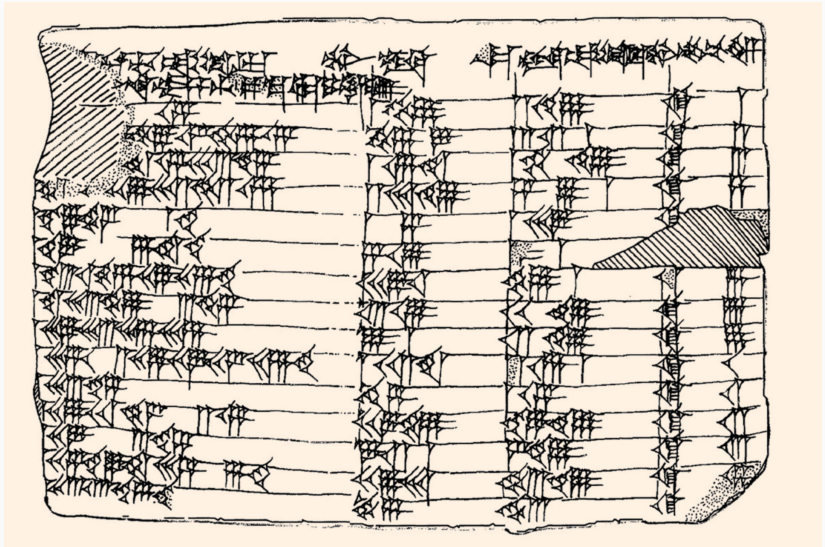
- Larsa (c. 1800 BCE) .
- Removed in 1920s.
- George Plimpton bought it, 1922.
- Left to Columbia University, 1936.
- It's about 13 by 9 by 2 cm.  
(Like a baking dish.)

- Four columns, cuneiform numbers.
- 15 rows - Pythagorean triples.
- 2nd column, side of right triangle.
- 3rd column, hypotenuse.
- 4th column, row number.
- What is the 1st Column?

# Plimpton 322 Clay Tablet - Homework!



# Sketch of the Plimpton 322 Tablet



# Babylonian Numerals 1-100 (Base 60)

1	┌	26	𐍪	51	𐍪┌	76	┌ 𐍪
2	┌┌	27	𐍪┌	52	𐍪┌┌	77	┌ 𐍪┌
3	┌┌┌	28	𐍪┌┌	53	𐍪┌┌┌	78	┌ 𐍪┌┌
4	┌┌┌┌	29	𐍪┌┌┌	54	𐍪┌┌┌┌	79	┌ 𐍪┌┌┌
5	┌┌┌┌┌	30	𐍪	55	𐍪┌	80	┌ 𐍪
6	┌┌┌┌┌┌	31	𐍪┌	56	𐍪┌┌	81	┌ 𐍪┌
7	┌┌┌┌┌┌┌	32	𐍪┌┌	57	𐍪┌┌┌	82	┌ 𐍪┌┌
8	┌┌┌┌┌┌┌┌	33	𐍪┌┌┌	58	𐍪┌┌┌┌	83	┌ 𐍪┌┌┌
9	┌┌┌┌┌┌┌┌┌	34	𐍪┌┌┌┌	59	𐍪┌┌	84	┌ 𐍪┌┌
10	┌	35	𐍪┌┌	60	┌	85	┌ 𐍪┌
11	┌┌	36	𐍪┌┌┌	61	┌┌	86	┌ 𐍪┌┌
12	┌┌┌	37	𐍪┌┌┌┌	62	┌┌┌	87	┌ 𐍪┌┌┌
13	┌┌┌┌	38	𐍪┌┌┌┌┌	63	┌┌┌┌	88	┌ 𐍪┌┌┌┌
14	┌┌┌┌┌	39	𐍪┌┌┌┌┌┌	64	┌┌┌┌┌	89	┌ 𐍪┌┌┌┌┌
15	┌┌┌┌┌┌	40	𐍪	65	┌┌	90	┌ 𐍪
16	┌┌┌┌┌┌┌	41	𐍪┌	66	┌┌┌	91	┌ 𐍪┌
17	┌┌┌┌┌┌┌┌	42	𐍪┌┌	67	┌┌┌┌	92	┌ 𐍪┌┌
18	┌┌┌┌┌┌┌┌┌	43	𐍪┌┌┌	68	┌┌┌┌┌	93	┌ 𐍪┌┌┌
19	┌┌┌┌┌┌┌┌┌┌	44	𐍪┌┌┌┌	69	┌┌┌	94	┌ 𐍪┌┌
20	𐍪	45	𐍪┌	70	┌┌	95	┌ 𐍪┌
21	𐍪┌	46	𐍪┌┌	71	┌┌┌	96	┌ 𐍪┌┌
22	𐍪┌┌	47	𐍪┌┌┌	72	┌┌┌┌	97	┌ 𐍪┌┌┌
23	𐍪┌┌┌	48	𐍪┌┌┌┌	73	┌┌┌┌┌	98	┌ 𐍪┌┌┌┌
24	𐍪┌┌┌┌	49	𐍪┌┌	74	┌┌┌	99	┌ 𐍪┌┌
25	𐍪┌┌	50	𐍪	75	┌┌┌	100	┌ 𐍪

# Akkadian Table of 9's

## 2 Akkadian Tablet (-1700)

In the paper "Sherlock Holmes in Babylon," *Amer. Math. Monthly* 87 (1980), 335-345, C. Buck describes Babylonian mathematics. He begins with a discussion of a clay tablet from 3700 years ago as shown in Table 2. There are four columns. You should convince yourself that this is a table of 9's.

𐎶	𐎶𐎵	𐎶𐎵	𐎶 𐎶𐎵
𐎶𐎶	𐎶𐎶𐎵	𐎶𐎶	𐎶𐎶 𐎶𐎵
𐎶𐎶𐎶	𐎶𐎶𐎶𐎵	𐎶𐎶𐎶	𐎶𐎶𐎶 𐎶𐎵
𐎶𐎶𐎶𐎶	𐎶𐎶𐎶𐎶𐎵	𐎶𐎶𐎶𐎶	𐎶𐎶𐎶𐎶 𐎶𐎵
𐎶𐎶𐎶𐎶𐎶	𐎶𐎶𐎶𐎶𐎶𐎵	𐎶𐎶𐎶𐎶𐎶	𐎶𐎶𐎶𐎶𐎶 𐎶𐎵
𐎶𐎶𐎶𐎶𐎶𐎶	𐎶𐎶𐎶𐎶𐎶𐎶𐎵	𐎶𐎶𐎶𐎶𐎶𐎶	𐎶𐎶𐎶𐎶𐎶𐎶 𐎶𐎵
𐎶𐎶𐎶𐎶𐎶𐎶𐎶	𐎶𐎶𐎶𐎶𐎶𐎶𐎶𐎵	𐎶𐎶𐎶𐎶𐎶𐎶𐎶	𐎶𐎶𐎶𐎶𐎶𐎶𐎶 𐎶𐎵
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Table 2: Table of 9's.

As an example, the last entry in the first column is  $12 = \text{𐎶𐎵}$ . Then,  $9 \times 12 = 108 = \text{𐎶 𐎶𐎵}$ . Note that in base 60 we have  $108 = 1(60) + 48$ .

In the second column is a one ( 𐎶 ) and 48 ( 𐎶𐎵 ) separated by a space. Buck introduces a slash notation to write this as 1/48.

It is easy to add in base 60. Buck gives the example  $14/28/31 + 3/35/45 = 18/4/16$ .

# Babylonian Squares

How can a table of squares be useful? In modern notation, we see that

$$ab = \frac{1}{4} [(a+b)^2 - (a-b)^2]. \quad (1)$$

Let's find the product  $11 \times 14$ . Using Table 3, the formula gives

$$\begin{aligned} 11(14) &= \frac{1}{4} [(11+14)^2 - (11-14)^2] \\ &= \frac{1}{4} (25^2 - 3^2) \\ &= \frac{1}{4} (10/25 - 9) \text{ (base 60)} \\ &= \frac{1}{4} (10/16) \text{ (base 60)} \\ &= \frac{1}{4} (10(60) + 16) = \frac{616}{4} = 154. \end{aligned} \quad (2)$$

𐎠	𐎠 𐎠	𐎠𐎠	𐎠 𐎠	10	1/40	19	6/1
𐎠𐎠	𐎠 𐎠	𐎠𐎠	𐎠 𐎠 𐎠	11	2/1	20	6/40
𐎠𐎠𐎠	𐎠 𐎠𐎠	𐎠𐎠	𐎠𐎠 𐎠	12	2/24	21	7/21
𐎠𐎠𐎠𐎠	𐎠 𐎠𐎠𐎠	𐎠𐎠𐎠	𐎠𐎠 𐎠𐎠	13	2/49	22	8/4
𐎠𐎠𐎠𐎠𐎠	𐎠 𐎠𐎠𐎠	𐎠𐎠𐎠	𐎠𐎠 𐎠𐎠𐎠	14	3/16	23	8/49
𐎠𐎠𐎠𐎠𐎠𐎠	𐎠 𐎠𐎠𐎠	𐎠𐎠𐎠	𐎠𐎠 𐎠𐎠𐎠	15	3/45	24	9/36
𐎠𐎠𐎠𐎠𐎠𐎠𐎠	𐎠 𐎠𐎠𐎠	𐎠𐎠𐎠	𐎠 𐎠𐎠𐎠	16	4/16	25	10/25
𐎠𐎠𐎠𐎠𐎠𐎠𐎠𐎠	𐎠 𐎠𐎠𐎠	𐎠𐎠𐎠	𐎠𐎠 𐎠𐎠𐎠	17	4/49	26	11/16
𐎠𐎠𐎠𐎠𐎠𐎠𐎠𐎠𐎠	𐎠 𐎠𐎠𐎠	𐎠𐎠𐎠	𐎠𐎠 𐎠𐎠𐎠	18	5/24	27	12/9

Table 3: Table of squares with Babylonian numerals in the left table and slash notation on the right side.

## 4 Pythagorean Triples

Another interesting tablet from the time is the Plimpton 322 tablet shown in Figure 4. This tablet has a listing of Pythagorean triples. The last column has a list of numbers from 1 to 15. Columns two and three seem to be the hypotenuse,  $C$ , and one leg,  $B$ , of the right triangle shown in Figure 1. Recall from the Pythagorean Theorem that

$$C^2 = B^2 + D^2.$$

The triple  $(D, B, C)$  is called a Pythagorean triple.

We now know that these triples are parametrized by the pair  $(a, b)$  as follows:

$$B = a^2 - b^2, \quad C = a^2 + b^2, \quad D = 2ab,$$

since

$$(a^2 - b^2)^2 + (2ab)^2 = (a^2 + b^2)^2.$$

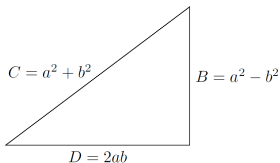


Figure 1: Right triangle with columns two and three as sides  $B$  and  $C$ , respectively. Pythagorean triples were later found to have a parametrization  $(a, b)$ .

# Transcription - Brackets indicate guesses

[59]/0/15	1/59	2/49	ki	1
[56/56]/58/14/50/6/15	56/7	1/20/25	ki	2
[55/7]/41/15/33/45	1/16/41	1/50/49	ki	3
53/10/29/32/52/16	3/31/49	5/9/1	ki	4
48/54/1/40	1/5	1/37	ki	[5]
47/6/41/40	5/19	8/1	[ki]	[6]
43/11/56/28/26/40	38/11	59/1	ki	7
41/33/45/14/3/45	13/19	20/49	ki	8
38/33/36/36	8/1	12/49	ki	9
35/10/2/28/27/24/26/40	1/22/41	2/16/1	ki	10
33/45	45	1/15	ki	11
29/21/54/2/15	27/59	48/49	ki	12
27/0/3/45	2/41	4/49	ki	13
25/48/51/35/6/40	29/31	53/49	ki	14
23/13/46/40	56	53	ki	[15]

# Sketch of the Plimpton 322 Tablet

il-ti si-li-ip -tim ib-sá		sag ib-sá si-li-ip-tim mu-bi-im	
na-as-sá-bu-ú-ma sag ti-ú			
15	159	249	ki 1
58145615	567	3121	ki 2
1153345	11641	1549	ki 3
5729325216	33149	591	ki 4
4854 14	15	137	ki 5
47 6414	519	81	
43115628264	3811	591	ki 7
413359 345	1319	249	ki 8
38333636	91	1249	ki 9
351 228 2724 264	12241	2161	ki 1
3345	45	115	ki 11
292154 215	2759	4849	ki 12
27 345	7121	449	ki 13
25485135 64	2931	5349	ki 14
2313 764	56	53	ki

Figure 6: Arabic numerals base 60. The bars designate place holders.

# Buck's Corrected Values

Second column - base 60 values for  $(B/D)^2$  with  $D^2 = C^2 - B^2$ .

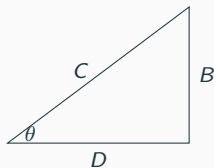
#	A	B	C	a	b
1	59/0/15	119	169	12	5
2	56/56/58/14/50/6/15	3367	4825	64	27
3	55/7/41/15/33/45	4601	6649	75	32
4	53/10/29/32/52/16	12709	18541	125	54
5	48/54/1/40	65	97	9	4
6	47/6/41/40	319	481	20	9
7	43/11/56/28/26/40	2291	3541	54	25
8	41/33/45/14/3/45	799	1249	32	15
9	38/33/36/36	481	769	25	12
10	35/10/2/28/27/24/26/40	4961	8161	81	40
11	33/45	45	75	1	0.5
12	29/21/54/2/15	1679	2929	48	25
13	27/0/3/45	161	289	15	8
14	25/48/51/35/6/40	1771	3229	50	27
15	23/13/46/40	56	106	9	5

# First Column Computation

- Buck suggests column A is  $\left(\frac{B}{D}\right)^2$ .
- Others suggest  $\left(\frac{C}{D}\right)^2$  and missing left part of the stone had 1's.

Noting,

$$\left(\frac{C}{D}\right)^2 = 1 + \left(\frac{B}{D}\right)^2.$$



From row 1: 59/0/15 represents

$$\frac{59}{60} + \frac{0}{60^2} + \frac{15}{60^3} = \frac{14161}{14400}.$$

From row 1:  $B = 119$ ,  $C = 169$  :

$$\begin{aligned} B^2 &= 119^2 = 14161 \\ D^2 &= 169^2 - 119^2 = 14400 \\ \left(\frac{B}{D}\right)^2 &= \frac{14161}{14400}. \end{aligned}$$

# Decimal Equivalents for Column One

#	A	Decimal Value	$(B/D)^2$
1	59/0/15	0.9834027777777778	0.9834027777777778
2	56/56/58/14/50/6/15	0.949158552088692	0.949158552088692
3	55/7/41/15/33/45	0.918802126736111	0.918802126736111
4	53/10/29/32/52/16	0.886247906721536	0.886247906721536
5	48/54/1/40	0.815007716049383	0.815007716049383
6	47/6/41/40	0.785192901234568	0.785192901234568
7	43/11/56/28/26/40	0.719983676268862	0.719983676268862
8	41/33/45/14/3/45	0.692709418402778	0.692709418402778
9	38/33/36/36	0.6426694444444444	0.6426694444444444
10	35/10/2/28/27/24/26/40	0.586122566110349	0.586122566110349
11	33/45	0.5625000000000000	0.5625000000000000
12	29/21/54/2/15	0.489416840277778	0.489416840277778
13	27/0/3/45	0.4500173611111111	0.4500173611111111
14	25/48/51/35/6/40	0.430238820301783	0.430238820301783
15	23/13/46/40	0.387160493827161	0.387160493827161



- 1900-1600 BC.
- Field plan.
- Used Pythagorean triples to make accurate right angles for measuring boundaries.
- Proposes that Plimpton 322 is the world's oldest and most accurate trigonometric table. (8/2017) [Youtube](#)
- [Robson](#) does not view it that way.



D.F. Mansfield. Plimpton 322: A Study of Rectangles. Found Sci, published online August 3, 2021; [Paper](#).

# Babylonian Geometry

- Simple shapes.
- Interested in areas.
- Fields, subdivisions.
- Inclinations, slopes.
- seked, ukuklu, run/rise.

See N. Wildberger's [YouTube](#) and reference Neugebauer and Sachs, ed., 1945, *Mathematical Cuneiform Texts*.

Neugebauer and Sachs Introduced Plimpton 322.

Wildberger and Mansfield - Babylonian trigonometry based on ratios.

