# Ancient Egyptian Mathematics: Religion and Computation Techniques in the Pharaonic Times


## Fathi Saleh

*Professor of Computer Engineering at Cairo University*
*Ex–Director & Founder for the Centre of Documentation of Cultural & Natural Heritage, Cairo, Egypt*



### Abstract

It was not by accident or by try–and–error methods that ancient Egyptians had built those magnificent monuments which started with the pyramids five thousand years ago. It is by profound scientific knowledge, a fact which has good evidence in the various mathematical papyri that were discovered, which reflect the deep knowledge in Mathematics, Geometry and calculations. When one investigates the way the ancient Egyptians manipulated their Mathematics, one gets surprised by the virtual similarity between the Mathematics that were used at the time of the pharaohs and the ones used by computer systems today. We have only uncovered six principal papyri addressing Mathematics from the pharaonic era until now: *Reisner Papyrus*, the *Moscow Mathematical Papyrus* (*MMP*), the *Kahūn Papyrus*, the *Egyptian Mathematical Leather Roll* (*EMLR*), the *Rhind Mathematical Papyrus* (*RMP*), and the *Berlin Papyrus*. Each of the above sources contains a series of problems and their solutions. The most known papyrus of them all is the *Rhind Mathematical Papyrus* which is now on display at the British Museum. It contains 87 problems in addition to a table for the decomposition of two over odd numbers into unit fractions, which we are going to investigate in detail. We are also going to present briefly some hints concerning the inter–relations between Mathematics and the ancient Egyptian religious symbols (mainly the apotropaic sound *Eye of Horus*/*wḏ3t*).


## I. Introduction

Until now, we have found only six papyri addressing Mathematics from the time of the Pharaohs: the *Reisner Papyrus* (*RP*), the *Moscow Mathematical Papyrus* (*MMP*), the *Kahun Papyrus* (*KP*), the *Egyptian Mathematical Leather Roll* (*EMLR*), the *Rhind Mathematical Papyrus* (*RMP*) and the *Berlin Papyrus*. Each papyrus contains a series of problems and their solutions. The most famous is the *Rhind Mathematical Papyrus* which is now on display at the British Museum. It contains 87 problems in addition to a table for the decomposition of two over odd numbers into unit fractions. Once we get into investigation of the ancient Egyptian Mathematics, we discover immediately the great similarity between the Mathematics of the Pharaohs and that used in computer systems today. This shows clearly that the Egyptian Civilisation was based on deep knowledge of different aspects of scientific know–how which allowed them to build those magnificent buildings starting from the pyramids as early as three thousand years BC, to the great temples of Upper Egypt of the New Kingdom, down to the Ptolemaic Zodiacs of Dendara. In this paper, we are going to investigate the way the ancient Egyptians were dealing with their Mathematics. We are going also to briefly discuss the inter–relations between Mathematics and the ancient Egyptian religious symbols (mainly the apotropaic *eye of Horus*/*wḏ3t*), related not only to fractions but to the astronomical phenomena of lunar phases and lunar eclipses as well.

## II. MATHEMATICS, EGYPTOLOGY & INFORMATICS

After thanking warmly Dr Dr Amanda–Alice MARAVELIA for her corrections, additions and editing, I would like to emphasise one point: there are great similarities between the Mathematics used at the time of the Pharaohs and those used in computer systems today. This will be the basic axis of this paper and will be appropriately developed in the sequel. It would be interesting, to start with, to observe a timeline for the Egyptian civilization [FIG. 1] divided into centuries (500 BC, 1000 BC, 2000 BC, & c.) and into different historical eras (as e.g.: the Old Kingdom, the Middle Kingdom, the New Kingdom, as well as the Late, Hellenic, Roman and the Arabic Periods).

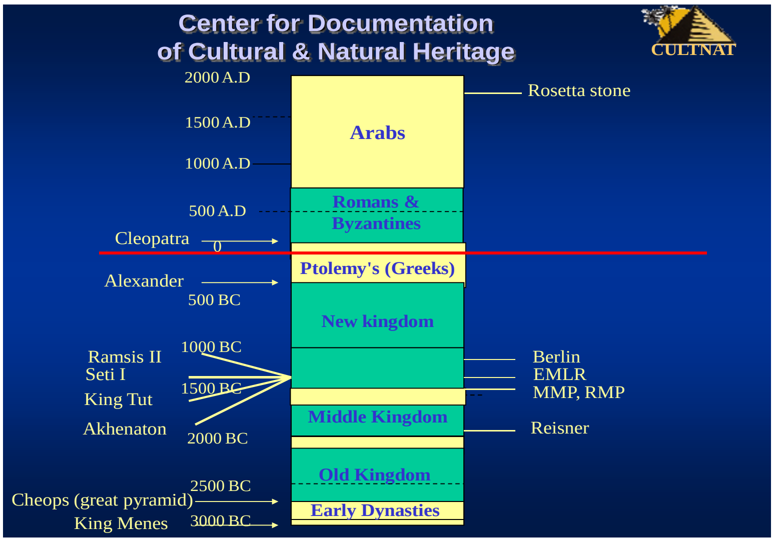



FIGURE 1: Timeline for the Egyptian Civilization, in relation to the most important mathematical sources.

The oldest of the six mathematical papyri is the *Reisner Papyrus* which dates back to 2200 BC. Then comes the *Rhind Mathematical Papyrus* which dates back to the year 1550 BC. This second papyrus says that it was copied from another one about 400 years earlier, which makes it closer in age to the aforementioned *Reisner Papyrus*. The *RMP* [FIG. 2] is a scroll about 5.2 m long. The

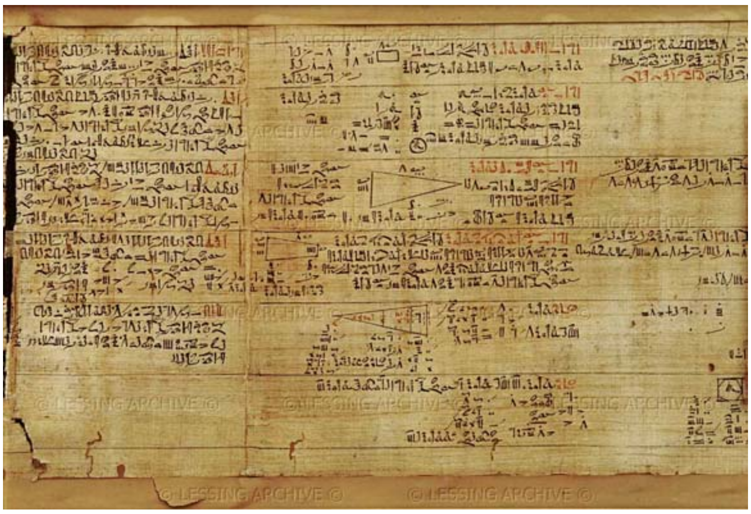
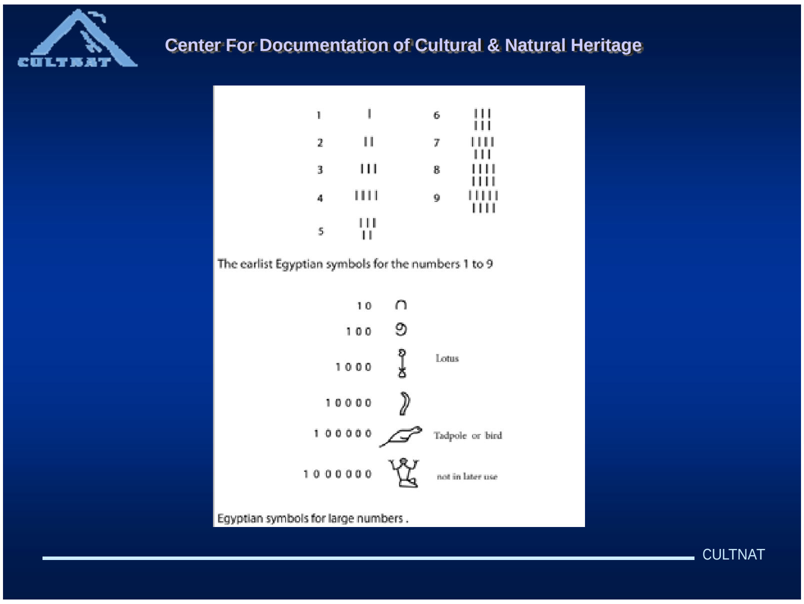
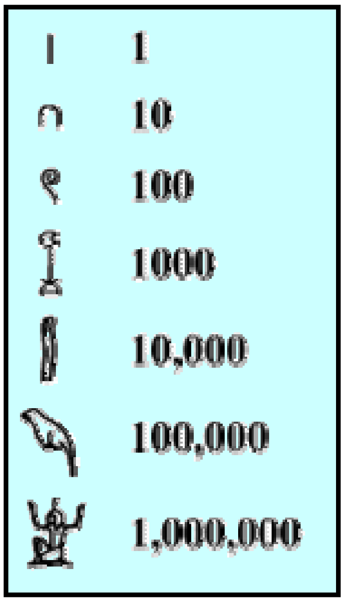


FIGURE 2: One of the most well–known pages of the RMP,
with its six problems for various geometrical computations.

British Museum displays the two major parts of it that they own, while the Brooklyn Museum in the United States displays some fragments of it that were found later. Papyri were made, in general, out of sheets of about A4 size, similar to what we use today. These sheets were put together to finally form the whole scroll. An example taken from the *RMP* **[FIG. 2]** shows one of the most well–known pages of this papyrus that was written in hieratic. This contains six famous problems. The first problem is for calculating the area of a rectangle; the second is for calculating the area of a circle, the third for calculating the area of a triangle; the fourth the area of a truncated triangle; and the fifth is for comparing triangles; & c.

**Let us start with Mathematics.** It is important to see how the ancient Egyptians noted their numbers **[FIG. 3-4]**. They actually used a decimal–based system: the *one* was one stroke, the *two* was two strokes, & c. They had also special symbols/numerals to denote the powers of 10: $10^0 = 1$, $10^1 = 10$, $10^2 = 100$, $10^3 = 1{,}000$, $10^4 = 10{,}000$, $10^5 = 100{,}000$, $10^6 = 1{,}000{,}000$). The number for *million* is represented by the god of myriads of years Heh (*Ḥḥ*) raising his hands to the sky.




**FIGURES 3-4:** Egyptian symbols for the numbers 1 to 9 and symbols for larger numbers (powers of 10).

A characteristic example of the use of numbers at the time of the Pharaohs must be also shown **[FIG. 5]**. In this case one should note the arithmetic operation of addition in hieroglyphic, hieratic and in our modern script too. One must also be aware of the fact that the ancient Egyptians usually wrote from right to left, as is the case with other Chamito–Semitic languages. Thus, if we want to write 24, we write the sign for *ten* twice and the sign for *one* four times; if we want to write 53, we write the sign for *ten* five times and the sign for *one* three times; and so forth. Then, if we want the sum of these two numbers, we put the signs for the two numbers one under the other, we place —for example— the *decades* under the *decades* and the *units* under the *units*. It is easy indeed to see the result. This consists of a very simple system that is also very easy to use.

We must also show some typical expressions that were repeatedly used by the ancient Egyptians in their mathematical texts and jargon, such as the following **[FIG. 6]**: *example of proof, therefore, find, total, thus doing as it occurs* and *working out*. There are also expressions of the following sort **[FIG. 7]**: *make then the multiplication, ⅔ to be added, ⅓ to be subtracted, to be added to it, you have correctly found it*, & c. In this figure, there is an interesting expression in the second line, namely the hieroglyphic sign that indicates addition (D54) takes the form of two feet facing

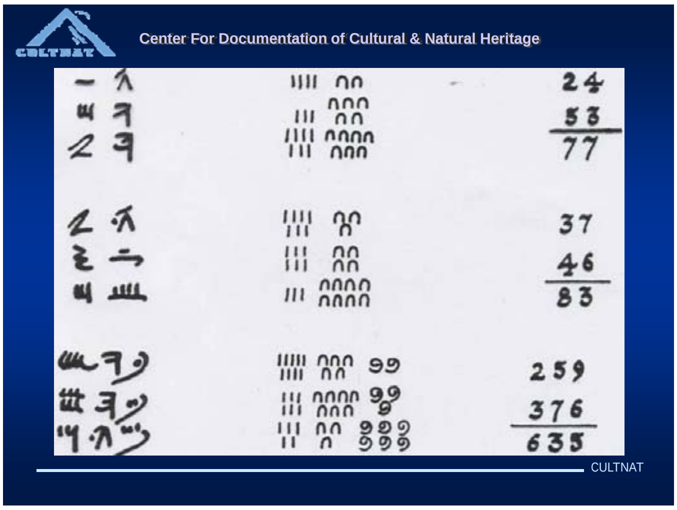
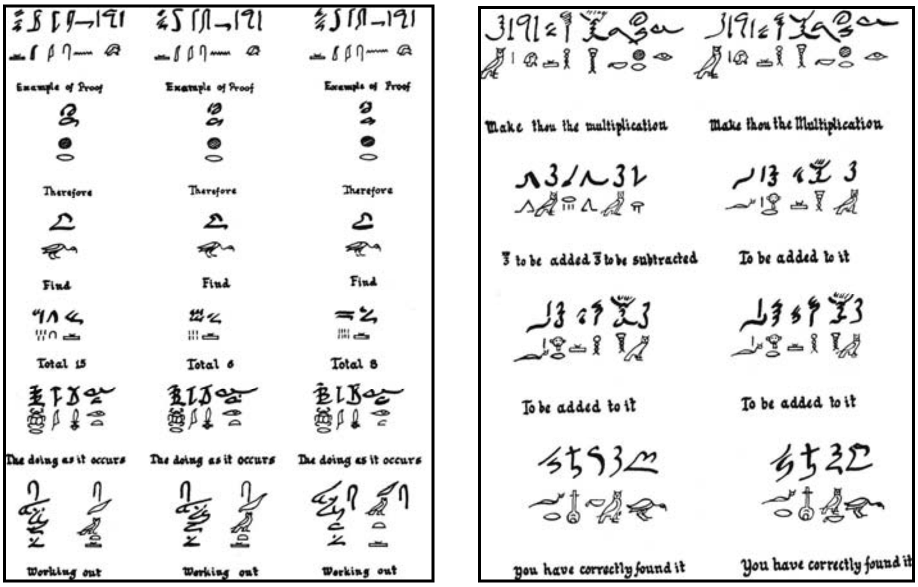



**FIGURE 5:** Examples for the addition of two numbers: Hieratic (left), Hieroglyphic (centre) and Hindu–Arabic (right).

a certain way (i.e.: the normal way for the ancient Egyptian direction of writing), while the sign for subtraction (D55) takes the form of two feet facing the opposite direction.




**FIGURES 6-7:** Examples of characteristic mathematical expressions that were used by the ancient Egyptians: *example/beginning of proof* (*tp n siti*); *therefore* (*ḫr*); *find* (*gm*); *total* (*dmd*); *doing as it occurs* (*irt mi ḫpr*); *calculating/working out* (*sšmt*); *if you make the multiplication of …* (*ir ḫr.k w3ḥ tp m …* ); *you (have) found (it) correctly* (*gm.k nfr*); & c.

## III. The Egyptian Mathematical Way of Thinking

We are now going to use a simple method, to show the way the ancient Egyptians used for their mathematical thought. In order to do this, we must necessarily refer to the decimal and the binary arithmetical systems, the fractions, as well as to the way modern computers are functioning.

**III.1. The Decimal System:** In order to explain the decimal system we use today, let us take as an example the number 256.37 **[Fig. 8]**. The digit 6 here is the nearest unit to the left of the decimal point; this means that it is worth 6, while 5, the second nearest, is worth 50 and the 2, the third nearest, that is worth 200. On the other hand, the 3, the nearest unit to the right of the decimal point is worth 3 over 10 and the 7, the second nearest after the decimal point, is worth 7 over 100. If we add all these values we get the answer. It is important to know that, according to the position of the digit in the number, it is multiplied by 10 to the power of that position.

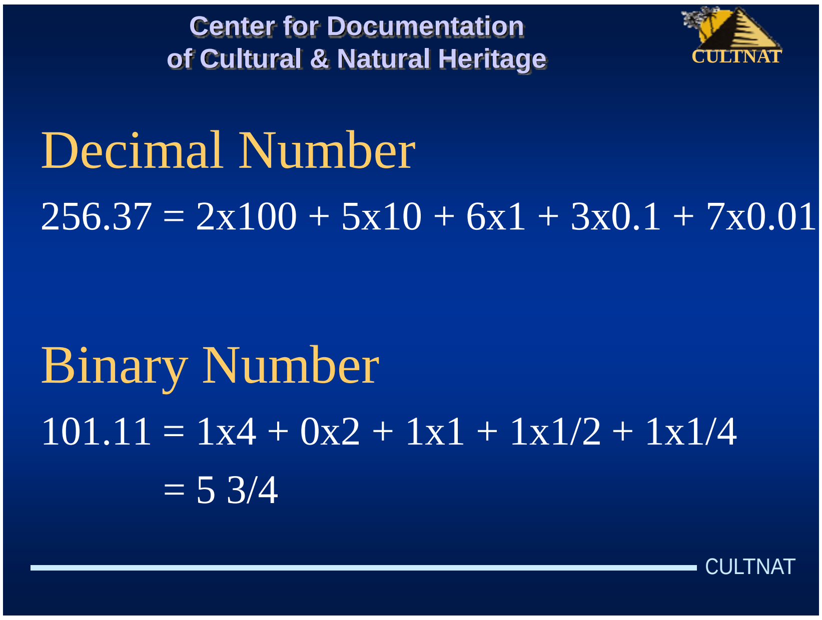
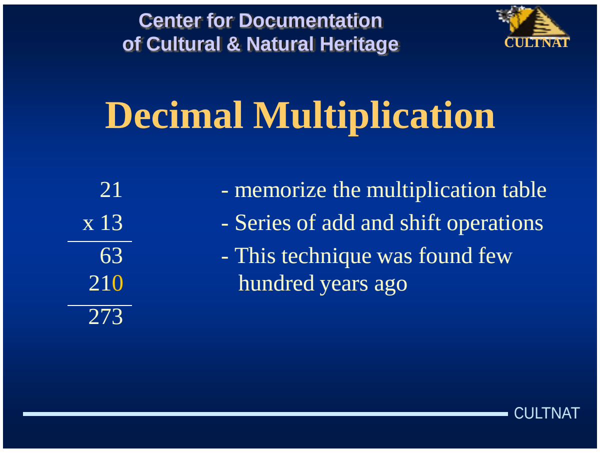


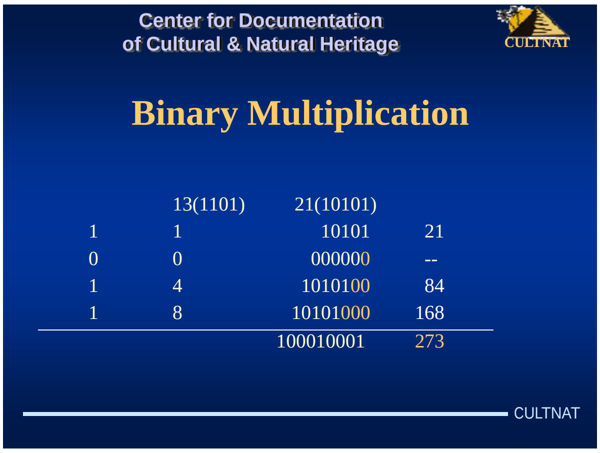

**FIGURE 8:** A paradigm for the expression of decimal and binary numbers.

**III.2. THE BINARY SYSTEM:** The same principle applies to the binary system [FIG. 8]. This is to say that, although in the decimal system we can have any of ten values between 0 and nine for every digit, in the binary system only two values are allowed for every digit, «0» and «1», however the two systems are treated in the same way. For example, if we have a binary number like 101.11, this is interpreted as follows: The «one» that comes first is worth 1, the «zero» that comes next is worth zero, the «one» that follows is multiplied by 2 x 2 = 4, & c. Thus the binary number 101 is equivalent to 5 (= 1 + 0 + 4). On the right side of the decimal point we have the first «1» worth ½ and then the second «1» worth ¼; thus the part to the right of the decimal point equals ¾. Thus, the total value of the binary number 101.11, in the decimal system, is 5 ¾.

**III.3. COMPUTER & BINARY FRACTIONS:** In the computer binary system we use only two values: «1» and «0». As for fractions, we use only binary unitary fractions like ½, ¼, ⅛, & c. This means that we do not use any numerator other than 1. We do not use e.g.: 2 over something or 5 over something. Also as denominators, we use only even numbers like 2, 4, 8, & c. and no other odd values such as e.g.: 3, 5, 7, & c. In spite of the fact that a computer uses a simple binary system and only unitary binary fractions, it is capable of performing complicated arithmtical operations. Normally, the computer does all its arithmetic in the binary system, including unitary binary fractions, and then transforms the result into decimal readable figures, so that we can read and understand it.

**III.4. PERFORMING MULTIPLICATIONS:** Let us now investigate how we perform multiplications in the decimal system. For example, multiplying 13 by 21 [FIG. 9], we normally multiply the 1 by 13 that gives 13, then we multiply 2 by 13 which gives 26. We then shift the 26 one position and add it to the 13 to get the final result of 273.



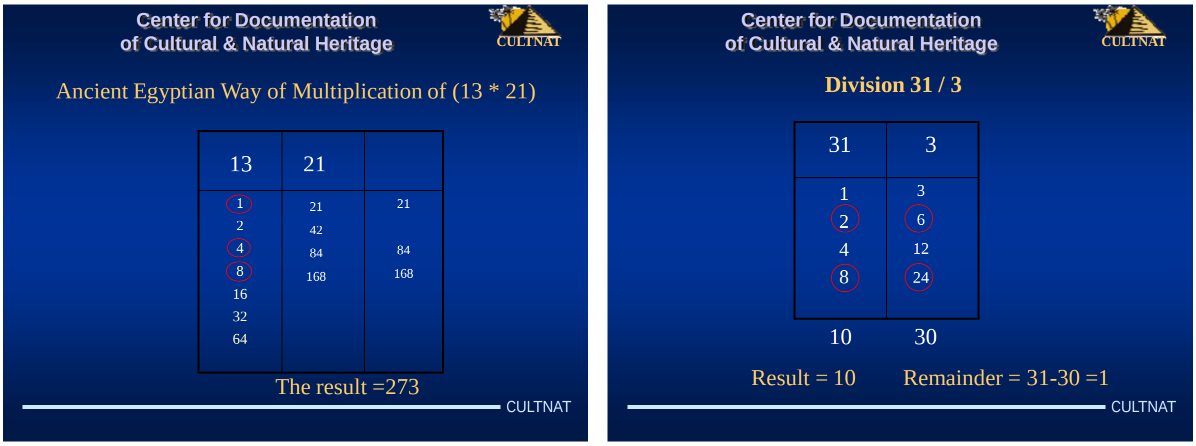

**FIGURES 9-10:** An example of ordinary (decimal) multiplication and an example of binary multiplication.

We should note here that, in order to perform this operation, we need to do two things. First, we have to memorize the multiplication table, which was only introduced five hundred years ago. Second, we have to use the multiplication table and, for the subsequent digits, we shift the result to the equivalent positions and add them together. So normally we go through a series of shift– and–add operations.

Now we will see how to apply the same principle for binary multiplications. If we use the last example again, i.e.: 13 times 21, the decimal number 13 is represented in the binary system as 1101 which is equivalent in decimal system to 1 + 0 + 4 + 8. The number 21 is represented in the binary system as 10101, which is equivalent in decimal system to 1 + 0 + 4 + 0 + 16. Now, in order to perform a binary multiplication, we use the *shift and add algorithm*. In the case of these two numbers, the binary system gives the table shown above **[FIG. 10]**. If we transform this table to the equivalent decimal numbers, this gives the values in the right–hand column of the same picture. This is the way a computer works to perform this addition operation.

**III.5. PERFORMING MULTIPLICATION BY THE ANCIENT EGYPTIANS:** Now we are going to see how the ancient Egyptians performed their multiplications. It is important to realise that the ancient Egyptians were very systematic. They created a procedure (an *algorithm* we would dare to say, using the modern computer language) and followed it systematically. The steps of the procedure they created to perform multiplications is as follows. *First step:* construct a table with the binary series of numbers 1, 2, 4, 8, 16, & c. *Second step:* put the two numbers you want to multiply at the head of the table. *Third step:* decompose the first number into its elements of the binary series. *Fourth step:* double the other number in every line in the table (remember that doubling a number means simply adding it to itself). *Fifth step:* mark the numbers in the right–hand column that correspond to the decomposed numbers in the left–hand column. *Sixth step:* add the marked numbers together to obtain the final result. Now let us take the example we used above, that is the multiplication of 13 by 21 **[FIG. 11]**. *First step:* we construct the table of the binary series 1, 2, 4, 8, & c. and we stop when the series exceeds the multiplier (13 in this case), so we stop at 8. *Second step:* we note the two numbers 13 and 21 at the top of the table. *Third step:* we decompose 13 into its components of the series (starting from the highest value which is 8 in this case). Then 8 + 4 = 12, and 12 + 2 = 14 (more than 13), so we drop the 2, and 8 + 4 + 1 = 13. *Fourth step:* we take the second number which is 21 and we put it in the first row of the second column. Then we double it successively: this gives 21, 42, 84 and 168. *Fifth step:* we mark the values of the second column (i.e.: 1, 4 and 8) which are

21, 84 and 168. *Sixth step:* We add the marked values of the right column to obtain the result, which is 273 in this case. If we compare the final table we have with the table delivered made by a computer **[FIG. 10]**, we observe that they are exactly the same.




**FIGURES 11-12:** An example showing the ancient Egyptian way of multiplying and dividing numbers (with a remainder ≠ 0).

**III.6. PERFORMING DIVISION BY THE ANCIENT EGYPTIANS:** Let us now see how the ancient Egyptians performed divisions. It is simply the inverse of the multiplication operation explained above. The second of the above figures **[FIG. 12]** shows how to perform the division. It is the same, but we start with the right column instead of the left column. For example, dividing 31 by 3, after we construct the table with the left–hand column containing the binary series 1, 2, 4, 8, & c. and the right–hand column by the doubling of 3 several times until we reach a value not exceeding 31 (3, 6, 12, 24), we dissolve 31 into its components, 24 and 6, which add up to 30. Then we select the corresponding values form the left–hand column, which are 8 and 2, which give 10. Thus, the answer is 10 and the remainder is 31 minus 30 which is 1.

**III.7. FRACTIONS:** As mentioned in the introduction, the way of thinking of the ancient Egyptians was very close to the way we design computer systems today. A computer, when dealing with fractions, treats them as binary unitary fractions. A unitary fraction is a fraction that has the numerator always equal to one. Examples are $\frac{1}{2}$, $\frac{1}{5}$, $\frac{1}{8}$, & c. Binary unit fractions are fractions that have as a denominator one of the binary series 2, 4, 8, 16, & c. Examples of binary fractions are $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$, & c. Any decimal fraction is substituted in the computer by its decomposition into binary fractions. For example $\frac{3}{8}$ is equivalent to $\frac{1}{4}$ and $\frac{1}{8}$. Or a fraction expressed in a binary system such as 0.1101 is equivalent to $\frac{1}{2} + \frac{1}{4} + 0 + \frac{1}{16}$, which is equal in our normal (i.e.: decimal) system to $\frac{13}{16}$. The ancient Egyptians used the fractions in a unitary form. Their expression for that was simple. They wrote the number as usual and then they added the hieroglyphic letter *r* on the top of it. Thus the fraction $\frac{1}{5}$ is represented as , using the ancient Egyptian connotation. To measure volumes, a special unit was used, the *hekat* (*ḥḳ3t*), which was equivalent to about 5 litres. The only fractions of *hekat* used were $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$, $\frac{1}{32}$, $\frac{1}{64}$, the same as the binary fractions used by computer systems. These binary fractions were written in a special way, quite unlike ordinary fractions. They were called *Horus Eye*–fractions, and were solely used for grain. In the next picture **[FIG. 13]** we can see these fractions represented in both hieroglyphic and hieratic scripts. They follow the so–called «Eye–Series»: $S_n = \frac{1}{2}n$ ($\forall\ n = 1, 2, 4, 8, 16$ & 32). The Eye of Horus was a particularly significant ancient Egyptian archetype, symbolizing both the final victory of Horus (as the son and avenger of his father Osiris) against Seth in the contendings between these two divinities for the throne of Egypt, hence the victory of good and Maᶜat (*M3ᶜt*) over evil (*isft*) and chaos, as well as the lunar phases of the waning and of the waxing moon (the complete and sound eye being the Full Moon), and finally —in addition— the lunar and the solar eclipses and the definite victory of light and resurrection against darkness and death. As an apotropaic amulet (*wḏ3t*), it was of the utmost importance for the funerary beliefs and practices of the ancient Nile–dwellers, considered as a powerful protection and an aversion talisman, used in thousands of burials throughout all eras of ancient Egyptian history. The Eye of Horus **[FIG. 16]** as a cosmographic symbol and as a source of mathematical symbolism for fractions consists of a characteristic example of the inter–relations between ancient Egyptian Meta–Physics and Religion, that is why we put particular emphasis on it in this paper.


**FIGURE 13: [LEFT]:** The sound *Eye of Horus/wḏ3t* (lower left) unitary fractions, in both hieroglyphic (lower right) and in modern connotation (centre and lower middle and right).
**[RIGHT]:** One of the funerary pectorals from the tomb of King Tutᶜankhamūn (Egyptian Museum, Cairo, JE 61.901), in the form of the Eye of Horus, with the corresponding fractions shown.

**III.8. THE *RMP* FRACTION TABLE:** The *Rhind Mathematical Papyrus* is divided into two parts. The first part (which was written on the *recto* of the papyrus) is a mathematical table which represents a table of decomposition of fractions of 2 divided by odd numbers into unit fractions. The second part of the *RMP* is a series of 87 mathematical and geometrical problems that continues on the *verso* of the papyrus (*Problems 1-60* were actually written on the *recto*, while the rest of the *Problems 61-87* were written on the *verso*). We shall concentrate on this fraction–part of the first section of the *recto*, which is the fraction table. Since the ancient Egyptians used the unitary fraction system to express fractions, it was necessary to have a sort of formula or tables, in order to show how to treat fractions other than unit fractions. In the *RMP* mathematical fraction list, the ancient Egyptians constructed a table that gives the decomposition of fractions of two over odd numbers between 3 and 101, into unitary fractions.

An aspect of this fraction table, using the modern arithmetical symbolism, shows the whole perception of the ancient Egyptians very clearly **[FIG. 14]**. Let us take a certain example: that with the divisor 19 for instance. We can see that the composite fraction of 2 over 19 can be written analyzed in a sum of unitary fractions as follows:

$$\frac{2}{19}=\frac{1}{12}+\frac{1}{76}+\frac{1}{114}$$

2/13 = 1/8 + 1/52 + 1/104

| Divisor | Unit Fractions | | | | Divisor | Unit Fractions | | | |
|---|---|---|---|---|---|---|---|---|---|
| 3 | 2 | 6 | | | 53 | 30 | 318 | 795 | |
| 5 | 3 | 15 | | | 55 | 30 | 330 | | |
| 7 | 4 | 28 | | | 57 | 38 | 114 | | |
| 9 | 6 | 18 | | | 59 | 36 | 236 | 531 | |
| 11 | 6 | 66 | | | 61 | 40 | 244 | 488 | 610 |
| 13 | 8 | 52 | 104 | | 63 | 42 | 126 | | |
| 15 | 10 | 30 | | | 65 | 39 | 195 | | |
| 17 | 12 | 51 | 68 | | 67 | 40 | 335 | 536 | |
| 19 | 12 | 76 | 114 | | 69 | 46 | 138 | | |
| 21 | 14 | 42 | | | 71 | 40 | 568 | 710 | |
| 23 | 12 | 276 | | | 73 | 60 | 219 | 292 | 365 |
| 25 | 15 | 75 | | | 75 | 50 | 150 | | |
| 27 | 18 | 54 | | | 77 | 44 | 308 | | |
| 29 | 24 | 58 | 174 | 232 | 79 | 60 | 237 | 316 | 790 |
| 31 | 20 | 124 | 155 | | 81 | 54 | 162 | | |
| 33 | 22 | 66 | | | 83 | 60 | 332 | 415 | 498 |
| 35 | 30 | 42 | | | 85 | 51 | 255 | | |
| 37 | 24 | 111 | 296 | | 87 | 58 | 174 | | |
| 39 | 26 | 78 | | | 89 | 60 | 356 | 534 | 890 |
| 41 | 24 | 246 | 328 | | 91 | 70 | 130 | | |
| 43 | 42 | 86 | 129 | 301 | 93 | 62 | 186 | | |
| 45 | 30 | 90 | | | 95 | 60 | 380 | 570 | |
| 47 | 30 | 141 | 470 | | 97 | 56 | 679 | 776 | |
| 49 | 28 | 196 | | | 99 | 66 | 198 | | |
| 51 | 34 | 102 | | | 101 | 101 | 202 | 303 | 606 |

2/69 = 1/46 + 1/138

**FIGURE 14:** The *RMP* fraction table for the decomposition of fractions of 2 over odd numbers into unitary fractions.

Many scientists have investigated this table and drawn a set of conclusions or criteria for selecting the proper decompositions. These rules were summarized by Gillings as follows: *Precept 1:* Of all the possible equalities, those with the smaller numbers are preferred, but none as large as 1,000*. *Precept 2:* An equality of only 2 terms is preferred to one of 3 terms, and one of 3 terms to one of 4 terms, but an equality of more than 4 terms is never used. *Precept 3:* The unit fractions are always set down in descending order of magnitude, that is, the smaller numbers come first, but never the same fraction twice. *Precept 4:* The smallness of the first number is the main consideration, but the scribe will accept a slightly larger first number, if it will greatly reduce the last number. *Precept 5:* Even numbers are preferred to odd numbers, even though they might be larger*, and even though the numbers of terms might thereby be increased.

**FIGURE 15:** Detail from a page of the *Rhind Mathematical Papyrus*, the most important ancient Egyptian mathematical manuscript, dealing with the calculation of the *slopes* (*sḳdw*) of pyramids. As an overlapping photo at the right bottom corner, one can see the complex of the Giza pyramids, one of the 7 Wonders of the Ancient World.

Gillings states that in 1967 an electronic computer was programmed to calculate all the possible unit fraction expressions of each of the divisions of 2 by the odd numbers 3, 5, 7, … 101, in order to compare the decompositions given by the *RMP* scribe with the thousands of possible positions. Such comparisons between the calculations of an ancient Egyptian scribe and the 22,295 values produced by a 20$^{th}$ Century computer, separated by a time span of nearly 4,000 years, are undoubtedly of great interest to the Historians of Mathematics, but to Egyptologists too! It took the computer five hours to execute this operation. Finally, we must note that the results of this table were reused in the solution of many other problems that need this type of fraction decomposition, on the papyrus. Interestingly the ancient Egyptian mathematical thought, through the use of practical/empirical methods and proto–scientific «algorithms», has managed to solve several problems and to offer a significant impetus into the foundation and even the preliminary conception of modern Mathematics.

**FIGURE 16:** Detail of a wall–painting from the tomb of Pashed (TT 3, Ramesside Period) at Deir ʾel-Medinah, showing the deceased as an adorer of the funerary god Ptah–Sokar (*Ptḥ-Zkr*) and of the *Eye of Horus* (*wḏ3t*).

## IV. CONCLUSIONS

It was not by accident or by try–and–error methods that ancient Egyptians had built those magnificent monuments which started with the pyramids five thousand years ago. It is by profound scientific knowledge, a fact which has good evidence in the various mathematical papyri that were discovered, which reflect the deep knowledge in Mathematics, Geometry and calculations. When one investigates the way the ancient Egyptians manipulated their Mathematics, one gets surprised by the virtual similarity between the Mathematics that were used at the time of the pharaohs and the ones used by computer systems today. The most known ancient Egyptian mathematical text is probably the *Rhind Mathematical Papyrus* which contains 87 problems in addition to a table for the decomposition of two over odd numbers into unit fractions, which we have investigated (in detail) in our paper. We have also given briefly some hints concerning the inter–relations between Mathematics and the ancient Egyptian religious symbols (mainly the apotropaic sound *Eye of Horus/wḏ3t* **[FIG. 16]** related not only to fractions but to the astronomical phenomena of lunar phases and lunar eclipses as well. Thus, in this paper, we presented a short but concise introduction as to how the ancient Egyptians performed their calculations. They clearly did so very systematically. Also, it is very surprising to discover that their systematic way of thinking is very close to the way computers perform calculations today. It is astonishing how they constructed their fraction tables, as is evident from the *Rhind Mathematical Papyrus*, which puzzled researchers who tried to find out the logic behind it. Indeed, the ancient Egyptians were great Scientists and Mathematicians. That is why they built such a unique civilization with such splendid monuments as the pyramids **[FIG. 15]**, monuments of a high cosmographic and meta–physical symbolism too.

## BIBLIOGRAPHY


AABOE, A.: *Episodes from the Early History of Mathematics*, Washington (Mathematical Association of America) [12]1998.

BRUINS, E.M.: «Ancient Egyptian Arithmetic: 2/N», *Indagationes Mathematicæ* (Nederl. Akad. Wetensch. Proc. Ser. **A.**), **14**, 1952, 81-91.

CHACE, A.B. (*et al.*): *The Rhind Mathematical Papyrus*, **I-II**, NY (Dover) [2]1969.

CLAGETT, M.: *Ancient Egyptian Science. A Source Book, **I**: Knowledge and Order*, PA (*Memoirs APS*, **184**) 1989, 263-406; ***II**: Calendars, Clocks and Astronomy*, PA (*Memoirs APS*, **214**) 1995.

COUCHOUD, S.: *Mathématiques égyptiennes: Recherches sur les connaissances mathématiques de l'Égypte pharaonique*, Paris 1993.

DILKE, O.A.W.: *Mathematics and Measurement*, London (BMP) 1987.

EVES, H.: *An Introduction to the History of Mathematics*, NY 1964.

GARDINER, A.H.: *Egyptian Grammar: Being an Introduction to the Study of Hieroglyphs*, Oxford (Griffith Institute / Ashmolean Museum) [3]1988.

GILLINGS, R.J.: «The Recto of the Rhind Mathematical Papyrus: How did the Ancient Egyptian Scribe prepare it?», *Archive for the History of Exact Sciences*, **12**[4], 1974, 291-98.

GILLINGS, R.J.: *Mathematics in the Time of the Pharaohs*, NY (Dover) [2]1982.

IMHAUSEN, A.: «Egyptian Mathematical Texts and their Contexts», *Science in Context*, **16**, Cambridge 2003A, 367-89.

IMHAUSEN, A.: *Ägyptische Algorithmen: eine Untersuchung zu den mittelägyptischen mathematischen Aufgabentexten*, Wiesbaden (*ÄgAbh*, **65** / Harrassowitz) 2003B.

MARAVELIA, A.–A. & SHALTOUT, M.A.M.: «The Great Temples of Thebes and the Sunrise in the Winter Solstice: Applying Modern Archæoastronomical Techniques to study the Ancient Egyptian Mansions of Millions of Years», *The Temples of Millions of Years & the Royal Power at Thebes in the New Kingdom: Science & New Technologies applied to Archæology* (Leblanc, C. & Zaki, G. eds), *Memnonia: Cahier Supplémentaire*, **2**, Cairo 2011, 283-95 & Pls. LVII-LX.

PEET, T.E.: «Mathematics in Ancient Egypt», *Bulletin of the John Rylands Library*, **15**[2], 1931, 409-41.

RISING, G.R.: «The Egyptian Use of Unit Fractions for Equitable Distribution», *Historia Math.*, **1**[1], 1974, 93-94.

ROBINS, G. & SHUTE, C.: *The Rhind Mathematical Papyrus*, London 1987.

SHERKOVA, T.A.: «"Oxo Xora": simvolika glaza v dodinastiheskom Egipte», *VDI*, **4**, 1996, 96-115.