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THE ASTOUNDING CONSISTENCY OF THE CALCULATION METHOD FOR THE CIRCUMFERENCE BETWEEN ANCIENT EGYPT AND ANCIENT CHINA

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ABSTRACT

The value of π was 3, which had been well documented in ancient classics and archaeological discoveries, including the Old Testament, ancient Egypt archaeology and ancient Chinese mathematical literature. The majority argues that this can be attributed to undeveloped, imprecise ancient mathematics, while the impeccable pyramids, withstanding 4 millennia, and the Dujiangyan, the large-scale project for irrigation and flood control, constructed around 256BC, still in use today, indicate that ancient mathematics thousands of years ago, was able to achieve accurate calculation. Nevertheless, this raises several questions, how to achieve accurate calculation when the value of π is 3? Is it possible that there is a huge difference between the ancient method of calculation and the method used in contemporary times? Based on extensive exploration of the Chinese mathematical classic Zhoubi Suanjing, multiplication table, and ancient Egyptian multiplication discovered in ancient Egypt archaeology, researchers have found the precise calculation method for computing the circumference of circles as π equals 3. Firstly, calculating the main value of the circumference when π was 3, then computing the difference value of the circumference by

the multiples "7, 8 and 9" and the accurate value of circumference of circles obtained with the combinations of the main value and the D value, which exhibits a high degree of precision that is no less than that of our current mathematical methodologies. This discovery, promoting more a profound understanding level of human civilization, not only fundamentally, originally facilitates the studies of ancient and modern mathematics but also serves as mathematical grounds for multiple fields research, including archaeology, history and theology.

INTRODUCTION

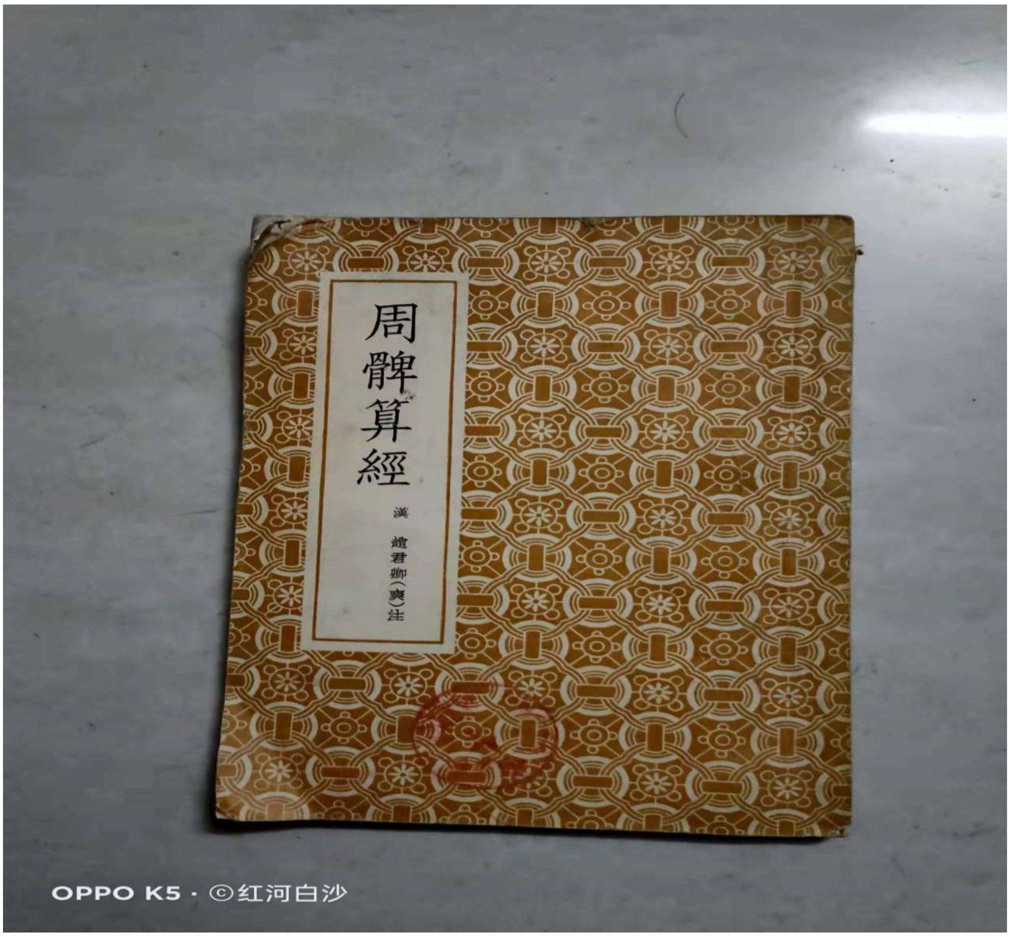


Figure 1. The ancient Chinese mathematical classic, Zhoubi Suanjing.

The right triangle in Zhoubi Suanjing is recorded as follows:

The mathematical calculation is based on the calculation of circle and square, of which the circle is calculated based on the square, and the square is drawn by tri-square (an L-shaped drawing tool derived from the multiplication table). The numerical values of "Gou (the shorter side), Gu (the longer side), and hypotenuse" (collectively referred to as Pythagorean triple) of a right triangle are set as 3, 4 and 5, respectively.

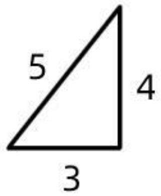
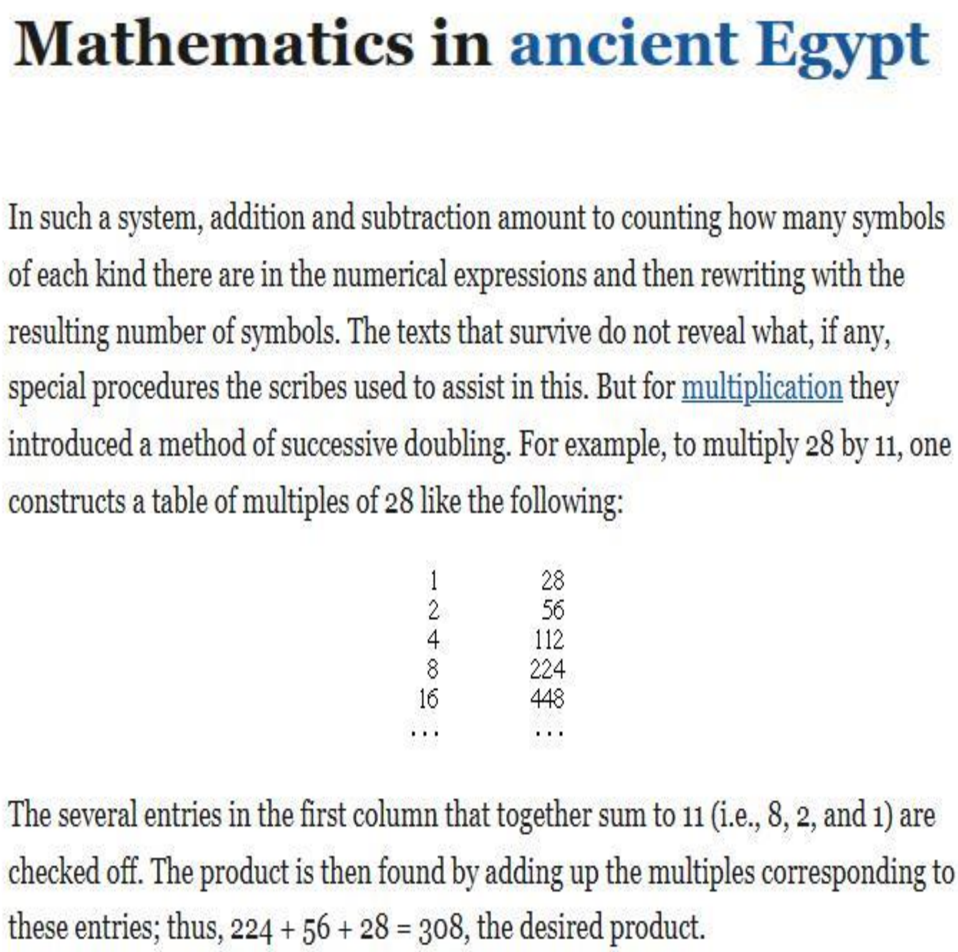


Figure 2. 3, 4 and 5 of right triangle.



Mathematics in ancient Egypt

In such a system, addition and subtraction amount to counting how many symbols of each kind there are in the numerical expressions and then rewriting with the resulting number of symbols. The texts that survive do not reveal what, if any, special procedures the scribes used to assist in this. But for multiplication they introduced a method of successive doubling. For example, to multiply 28 by 11, one constructs a table of multiples of 28 like the following:

1	28
2	56
4	112
8	224
16	448
. . .	. . .

The several entries in the first column that together sum to 11 (i.e., 8, 2, and 1) are checked off. The product is then found by adding up the multiples corresponding to these entries; thus, 224 + 56 + 28 = 308, the desired product.

Figure 3. Ancient Egypt multiplication.

https://www.britannica.com/science/mathematics/Mathematics-in-ancient-Egypt

The ancient Egyptian multiplication as shown in Figure 3, was found in the column of "Mathematics in ancient Egypt" from the Encyclopedia Britannica official website. However, Encyclopedia Britannica fails to provide a relatively convincing explanation for the ancient Egyptian multiplication.

Multiplication table

1×1=1
1×2=2 2×2=4
1×3=3 2×3=6 3×3=9
1×4=4 2×4=8 3×4=12 4×4=16
1×5=5 2×5=10 3×5=15 4×5=20 5×5=25
1×6=6 2×6=12 3×6=18 4×6=24 5×6=30 6×6=36
1×7=7 2×7=14 3×7=21 4×7=28 5×7=35 6×7=42 7×7=49
1×8=8 2×8=16 3×8=24 4×8=32 5×8=40 6×8=48 7×8=56 8×8=64
1×9=9 2×9=18 3×9=27 4×9=36 5×9=45 6×9=54 7×9=63 8×9=72 9×9=81

The content of the multiplication table had been cited in different Chinese ancient classics as early as in the Spring and Autumn-Warring States Period (770 BC-221 BC). During the archaeological excavation of the site of Liye Ancient City in Longshan County (Hunan Province, China) in 2002, archaeologists discovered up to 38,000 pieces of bamboo slips made in the Qin dynasty (221 BC), including those recording the multiplication table.

Figure 4. Bamboo slips of the Qin Dynasty discovered at the site of Liye Ancient City.

The literature pertinent to π=3:

1. The Old Testament: it is widely, almost universally, believed that the Hebrew Bible gives the value of π as the crude approximation 3.
'And he made a molten sea, ten cubits from one brim to the other: it was round all about, and his [i.e. its] height was five cubits: and a line of thirty cubits did compass it round about.'
2. The Ancient Egypt: ancient Egyptians set π as 3 in the Egyptian demotic mathematical text P.Cairo.
3. The Han Dynasty: the common practice in China before the Han Dynasty (206 BC–220 AD) was to take the ratio of π=c/d as 3.

ANALYSIS

1. Ancient Chinese multiplication table，2. Ancient Egyptian multiplication.

1. Multiplication table

Part 1
1×1=1
1×2=2 2×2=4

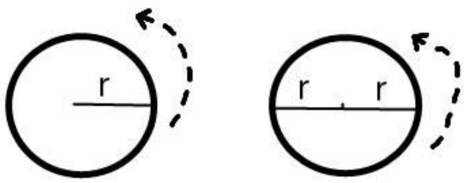


Figure 5. Drawing a circle in ancient times.

There are two basic methods for drawing a circle:

The first is to draw a circle by rotating a rope around the center, and the circle is formed by a radius.

The second is to draw a circle by rotating a wooden pole, with the central point of the wooden pole as the circle center. In this way, the circle is formed by diameter.

In ancient characters, the radius and diameter are presented as a transverse one ("一").

The circle formed by either radius or diameter results from the rotation of a transverse "一", and two "一" representing the radius equal to one "一"

standing for the diameter, thus generating "1×1=1" in the multiplication table. Therefore, "1×1=1" of the multiplication table refers to the circle formed by radius or diameter.

It has been mentioned in the Zhoubi Suanjing that "Square is drawn by tri-square".

Figure 6. Tri-square(L-shaped drawing tool).

Tri-square is a drawing tool in ancient China, basically shaped as a square ruler. As it is made of two sides, the tri-square represents the numerical value two ("二"). One gnomon stands for one "二", and the sum of two gnomons is four. Besides, two tri-squares can constitute a square, so "1×2=2 2×2=4" of the multiplication table indicates the square formed by the tri-square.

Figure 7. Two tri-squares constitute a square.

According to Part 1 of the above analysis, "1×1=1" of the multiplication table referred to the circle, and "1×2=2 2×2=4" indicated the square. Hence, the two words "circle and square" could be applied to express Part 1 of the multiplication table.

It has been stated in the Zhoubi Suanjing that "Mathematical calculation is based on the calculation of circle and square. Part 1 of the multiplication table exactly referred to the "circle and square", demonstrating that the multiplication table is a calculation method for the "circle and square".

Part 2
1×3=3 2×3=6 3×3=9
1×4=4 2×4=8 3×4=12 4×4=16
1×5=5 2×5=10 3×5=15 4×5=20 5×5=25

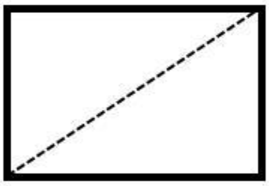


Figure 8. Structure of square.

It is well known that any square consists of two right triangles. Hence, the calculation of a right triangle is the basic method for calculating a square.

In about 2500 BC, Pythagoras, an ancient Greek mathematician, not only demonstrated that the square of the hypotenuse of a right triangle was equal to the sum of the square of the two sides ($a^2 + b^2 = c^2$), but also found that the minimum integer values of a right triangle were "3, 4 and 5".
In around 2100 BC, it was clearly indicated in the Chinese ancient mathematical classic Zhoubi Suanjing that the Pythagorean triples of a right triangle were "3, 4 and 5".

Thus, it can be inferred that the numerical values "3, 4 and 5" of a right triangle are a set of standard numeral values that comply with the Pythagorean theorem and may represent the right triangle.

Table 1. Pythagorean number in the multiplication formula table.

	1-fold	2-fold	3-fold	4-fold	5-fold
3	1×3=3	2×3=6	3×3=9	4×3=12	5×3=15
4	1×4=4	2×4=8	3×4=12	4×4=16	5×4=20
5	1×5=5	2×5=10	3×5=15	4×5=20	5×5=25
Pythagorean triples of the right triangle					
	3,4 and 5	6,8 and 10	9,12 and 15	12,16 and 20	15,20 and 25

As shown in Table 1, Part 2 of the multiplication table lists the calculation of the standard numerical values "3, 4 and 5" of a right triangle, and the 1-fold to 5-fold calculation results of "3, 4 and 5" are the five sets of Pythagorean triples of a right triangle.

Therefore, Part 2 of the multiplication table is a rapid method for calculating the standard numerical values of a right triangle.

Such a rapid calculation method is characterized by the common multiple of "3, 4 and 5", and the other two numerical values can be rapidly calculated with only one known numerical value of a right triangle as long as the multiple remains the same.

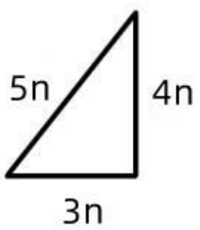


Figure 9. Standard numerical values.

Where, "3, 4 and 5" are the standard numerical values of right triangles, and *n* stands for multiple, whose value can be any numerical value greater than zero. Therefore, the Pythagorean triples of all the right triangles meeting the numerical values "3, 4 and 5" can be rapidly calculated through "3n, 4n and 5n".

As any square is composed of two right triangles, the calculation of right triangles is exactly the calculation of squares. Hence, Part 2 of the multiplication table is a basic method for calculating squares.

Part 3
1×6=6 2×6=12 3×6=18 4×6=24 5×6=30 6×6=36

Circumference ratio, namely, the ratio of the circumference of a circle to its diameter, is usually expressed as the Greek letter π.

Given π≈3.141592653589793238462643..., the approximate value 3.14 is often taken for the calculation.

Circumference: C=πd=2πr (where, *C* means circumference, *d* stands for

diameter, and *r* represents radius)
When the numerical value of diameter was 1, C=πd=1×π=3.14.
When the numerical value of radius was 1, C=2πr=2×π×1=6.28.
When the numerical value of radius was 1, while that of diameter was 2, d=2r.

Therefore, it was found that the numerical values of the circumference of the circles with a radius of "1, 2, 3, 4, 5 and 6" were "6.28, 12.56, 18.84, 25.12, 31.4 and 37.68", respectively.

Subsequently, this set of numerical values of the circumference was compared with Part 3 of the multiplication table.

r=1, 2, 3, 4, 5, 6
1×6=6 2×6=12 3×6=18 4×6=24 5×6=30 6×6=36
6, 12, 18, 24, 30, 36
6.28, 12.56, 18.84, 25.12, 31.4, 37.68

It could be discovered through comparison that there was a difference (D value) between the numerical values in Part 3 of the multiplication table and the actually calculated numerical values of the circumference:

When the numerical values of radius were 1, 2, 3, 4, 5 and 6, the D values of the circumference were 0.28, 0.56, 0.84, 1.12, 1.4 and 1.68, respectively.

Without concerning the D value, the contents of Part 3 of the multiplication table were the numerical values of the circumference "6, 12, 18, 24, 30, and 36" of a circle, with a radius of "1, 2, 3, 4, 5 and 6", respectively, and π was set as 3.

r=1, C=2πr =2×3×1=6
r=2, C=2πr =2×3×2=12
r=3, C=2πr =2×3×3=18
r=4, C=2πr =2×3×4=24
r=5, C=2πr =2×3×5=30
r=6, C=2πr =2×3×6=36

It can be seen that "2×3" is a fixed value when the circumference is calculated based on the radius, *i.e.* 2π=6, where *π* is taken as 3.

Hence, the circumference difference in Part 3 of the multiplication table was a calculation method, in which the radius was multiplied by 2π.
With the radius was set as 1 and 2, circumference =1×2π=1×6=6 and 2×2π=2×6=12, resulting in the multiplication formula "1×6=6" and "2×6=12", respectively.

Similarly, the rest of Part 3 of the multiplication table was calculated according to the multiplication of radius by 2π.

2π was a constant in Part 3 of the multiplication table for calculating the circumference, namely, $2\pi=6$.

Therefore, the calculation method for the circumference without concerning the D value is as follows: C=6r, where *r* can be any numerical value greater than zero.

Part 4
1×7=7 2×7=14 3×7=21 4×7=28 5×7=35 6×7=42 7×7=49
1×8=8 2×8=16 3×8=24 4×8=32 5×8=40 6×8=48 7×8=56 8×8=64
1×9=9 2×9=18 3×9=27 4×9=36 5×9=45 6×9=54 7×9=63 8×9=72 9×9=81

Part 4 covers the last group of numerical values in the multiplication table. In this part, the first three numerical values in the first column of this group were explored in the first place:

1×7=7 1×(3+4)=7
1×8=8 1×(4+4)=8
1×9=9 1×(5+4)=9

Two groups of numerical values, namely, "3, 4 and 5" and "4, 4 and 4" in the right column, were obtained by breaking down the multipliers "7, 8 and 9" in the left column.

The group of "3, 4 and 5" apparently denoted the standard numerical values of the right triangle. The relationship between the numeral "4" and the standard numerical values "3, 4 and 5" of the right triangle was further explored.

Table 2. Part 4 of the multiplication table dedicated to the D value of the circumference.

Circumference: C=6r							
Radius	$r=\frac{1}{4}$	$r=\frac{2}{4}$	$r=\frac{3}{4}$	$r=\frac{4}{4}$	$r=\frac{5}{4}$	$r=\frac{6}{4}$	$r=\frac{7}{4}$
Circumference	1.5	3	4.5	6	7.5	9	10.5
Circumference: C=2πr							
Radius	$r=\frac{1}{4}$	$r=\frac{2}{4}$	$r=\frac{3}{4}$	$r=\frac{4}{4}$	$r=\frac{5}{4}$	$r=\frac{6}{4}$	$r=\frac{7}{4}$
Circumference	1.57	3.14	4.71	6.28	7.85	9.42	10.99

D value between C=6r and C=2πr							
D value	0.07	0.14	0.21	0.28	0.35	0.42	0.49
Part 4 of the multiplication table (first column)							
	1×7=7	2×7=14	3×7=21	4×7=28	5×7=35	6×7=42	7×7=49

As shown in the circumference comparison Table 3, Part 4 of the multiplication table is dedicated to the calculation of D value of the circumference.

A numerical value of 7 was obtained for each segment when the radius of the circle was evenly divided into 4 parts, with the total numerical value of the 4 equal segments amounting to 28.

The D value of the circumference rose by 7 as the radius of the circle increased.

There were 4 equal segments when the radius of the circle stood at 1, with each equal segment being 7 in the numerical value and a total numerical value of 28 for the 4 equal segments.

There were 8 equal segments when the radius of the circle reached 2, with each equal segment being 7 in the numerical value and a total numerical value of 56 for the 8 equal segments.

According to the aforementioned analysis, the numerals of "4, 4 and 4" after the standard numerical values of the right triangle ("3, 4 and 5") denoted the 4 equal segments of the radius of the circle.

Since the 4 equal segments were acquired by evenly dividing the radius of the circle into 4 sections, the numerical values "3, 4 and 5" that were added to the numerals "4, 4 and 4", could represent the 4 equal segments to obtain "7, 8 and 9" and also referred to the radius of the circle. In other words, the numerical values of the radius of the circle should be taken within the value range fitting the "$3n$, $4n$ and $5n$" characteristic of the right triangle. Regardless of whether the radius of a circle stands at $3n$, $4n$, or $5n$ in nature, the D value of its circumference can be calculated by dividing its radius into 4 equal segments.

Table 3. Three calculation methods for D value in Part 4 of the multiplication table.

Three calculation methods for D value in Part 4 of the multiplication table									
Radius									
3n	1×7= 7	2×7= 14	3×7= 21	4×7= 28	5×7= 35	6×7= 42	7×7= 49		
4n	1×8= 8	2×8= 16	3×8= 24	4×8= 32	5×8= 40	6×8= 48	7×8= 56	8×8= 64	
5n	1×9= 9	2×9= 18	3×9= 27	4×9= 36	5×9= 45	6×9= 54	7×9= 63	8×9= 72	9×9= 81

When the 3n method was applied, the radius of the circle indicated a multiple of 3 in numerical value, with n valued as any number greater than zero.

For the application of the 4n method, a multiple of 4 was implied for the radius of the circle, with n valued as any number greater than zero.

As for the 5n method, the radius of the circle was a multiple of 5, with n valued as any number greater than zero.

When the radius of the circle stood at 3n, 4n and 5n, it was divided into 4 equal segments with each being 7, 8 and 9 in the numerical values and the D values of the circumference increased by 7, 8 and 9, respectively, as the radius of the circle increased (Table 3).

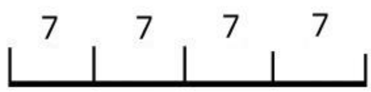


Figure 10. Quartering of radius with the value of 3n.

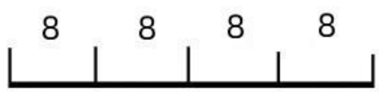


Figure 11. Quartering of radius with the value of 4n.

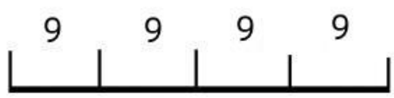


Figure 12. Quartering of radius with the value of 5n.

For instance:

There were 24 equal segments when the radius of the circle was 6 (3n=3×2), with each equal segment valued at 7. Therefore, the D value of the circumference was 24×7=168 (1.68).

The radius of the circle was divided into 64 equal segments when it reached 16 (4n=4×4), with each equal segment standing at 8 in the numerical value and the D value of the circumference being 64×8=512 (5.12).

A total of 100 equal segments existed when the radius of the circle amounted to 25 (5n=5×5), with each equal segment valued at 9. As a result, the D value of the circumference was 100×9=900 (9.00).

Therefore, Part 4 of the multiplication table is as good as a tool for calculating the D value of the circumference. Based on the three characteristics of the numerical values of the radius ("3*n*, 4*n* and 5*n*"), three calculation methods for the D value of circumference, featured by the multiples of "7, 8 and 9", respectively, were categorized accordingly.

The circumference calculation formula reflected by the multiplication table is listed as follows:

C=6r + D value of the circumference (*r* stands for the radius of the circle).

Based on above analysis, the whole process of calculation for computing the circumference of circles discovered in the ancient Chinese multiplication table was composed of two parts. The main value of the circumference (6r) can be firstly obtained as π equals 3. Then, according to each equal part value "7, 8, 9", corresponding to the values of radius "3n, 4n, 5n" respectively, the D value of circumference of circles can be acquired secondly. Furthermore, the combination of two values was the precise value of the circumference of circles. Therefore, during the ancient era, the accurate calculation result of the circumference was still able to achieve when the value of π was set as 3.

2. The ancient Egyptian multiplication

1	28
2	56
4	112
8	224
16	448
...	...

Figure 13. The ancient Egyptian multiplication.

a. The multiple relationship

Two columns from ancient Egyptian multiplication express the multiple relationship, in which "2, 4, 8, 16" are all integer multiples of "1", and "56, 112, 224, 448" are all integer multiples of "28". Additionally, the multiple of the left column is identical to the multiple in the right column. To be specific, when "2" is twice value of "1", and "56" is also twice value of "28". Therefore, it is contended that "1=28 and 2=56". However, under what conditions could "1" be equal to "28"?

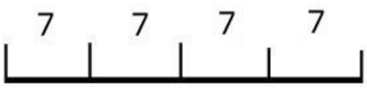


Figure 14. Dividing a line segment into four equal parts with each part value of 7.

In the exploration of ancient Chinese multiplication table, the ancient accurate calculation method for computing the circumference involved dividing a line segment into four equal parts. Consequently, "1=28" in ancient Egyptian multiplication refers to the value "28" of a line segment and the value of two segments is "56", with a value of 7 for each part in the quartering of a line segment.

Table 4. The ancient calculation method for computing segments

The quartering of a line segment, with a value of 7 for each equal part			
The quantity of segments	The overall quantity of equal segments	The process of calculation	The result of calculation
1	4	4×7=28	28
2	8	8×7=56	56
4	16	16×7=112	112
8	32	32×7=224	224
16	64	64×7=448	448

Nevertheless, for what purpose was the ancient Egyptian method of dividing a line segment into four equal parts employed in the calculation?

b. The calculation method of circumference and π=3

Table 5. The calculation of circumference of circles

The radius of circles	2πr，π=3.14	6r，π=3	D value between C=6r and C=2πr
1	2×3.14×1=6.28	6×1=6	28（0.28）
2	2×3.14×2=12.56	6×2=12	56（0.56）
4	2×3.14×4=25.12	6×4=24	112（1.12）
8	2×3.14×8=50.24	6×8=48	224（2.24）
16	2×3.14×16=100.48	6×16=96	448（4.48）

From the view of the calculation method of the circumference "C=6r+D" discovered in the ancient Chinese multiplication table, the method for computing the circumference of circles employed by ancient Egyptian exactly refers to "C=6r+D", namely, the sum of main value and D value when π is taken as 3. Consequently, the ancient Egypt multiplication documented in Encyclopedia Britannica, in fact, is exactly the calculation method for computing the D value of circumference rather than common multiplication.

Table 6. The calculation method of D value employed by ancient Egyptian

Radius	The D value of the circumference
1	1×28=28
2	2×28=56
4	4×28=112
8	8×28=224
16	16×28=448

Through the exploration of the ancient Egypt multiplication recorded in Encyclopedia Britannica, there were two steps involved in Egyptians' calculation methods of the circumference under the condition that π equals 3. Firstly, acquiring the main value of the circumference by 6r; secondly, obtaining the D value of the circumference by the basic value "28". Then, the combination of the main value and the D value is the accurate value of the circumference of circles. Therefore, according to Table 4, 5, 6, Egyptians' calculation formula for computing the circumference of circles is as follows:

C=6r+28r
Radius×6 equals the main value
Radius×28 equals the D value
"6 and 28" are core values of the circumference of circles

Given any positive radius of a circle, the exact value of its circumference can be directly calculated using the core numerical values "6 and 28".

Therefore, the ancient Egypt multiplication documented in Encyclopedia Britannica is the calculation method for the D value of the circumference as π equals 3, and 28 is taken as the basic value.

CONCLUSION

The calculation method for computing the D value of circumference included under the column "Mathematics in ancient Egypt" from Encyclopedia Britannica provides evidence supporting the accuracy of the recordings of π as 3 was documented in ancient Chinese classics and The Old Testament. Consequently, the D value calculation method, even with the value 3 for π, is still able to achieve the accurate calculation for the circumference of circles. This is why the incredibly precise and enduring pyramids have stood for over 4000 years, as well as ancient large-scale hydraulic engineering projects such as the Dujiangyan irrigation system that are still in use today.

There is an astounding consistency of the calculation method "C=6r+D" for computing the circumference of circles between multiplication table within ancient Chinese classics and ancient Egyptians' methods. The only difference is that in ancient Egypt multiplication, the value of each equal part of a line segment is 7, which remains unchanged for any radius given, while the counterpart in the ancient Chinese multiplication table changes as the value of radius changes, exhibiting "7, 8, 9" for each equal part, corresponding to the different values of radius "3n, 4n, 5n" respectively.

Through analysis of the ancient Chinese multiplication table and the calculation method for computing the D value of the circumference, it is suggested that there is a novel insight of ancient human civilization, in other words, the remote ancient times were not an era characterized by undeveloped mathematics and science, but rather a period that remains insufficiently understood by us today. The discovery of the calculation method of the D value of the circumference from multiplication table provides significant evidence that dating back to more than 4000 or 5000 years, humans had already acquired remarkably advanced and precise calculation techniques, which were adeptly employed in the construction of major engineering projects.

The calculation method for computing the circumference of circles in ancient China and Egypt as π is taken as 3.

C=6r+D, with the value of each equal part of "7, 8, 9", corresponding to the value of radius "3n, 4n, 5n" respectively

C=6r+28r, with the value of each equal part of 7

The core part of two methods

Calculating the main value and D value Separately. Then, the combination of two values is the accurate value of circumference of circles.

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