

On a Simpler, Much More General and Truly Marvellous Proof of Fermat's Last Theorem

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English mathematics Professor, Sir Andrew John Wiles of the University of Cambridge finally and conclusively proved in 1995 Fermat's Last Theorem which had for 358 years notoriously resisted all gallant and spirited efforts to prove it even by three of the greatest mathematicians of all time – such as Euler, Laplace and Gauss. Sir Professor Andrew Wiles's proof employs very advanced mathematical tools and methods that were not at all available in the known World during Fermat's days. Given that Fermat claimed to have had the 'truly marvellous' proof, this fact that the proof only came after 358 years of repeated failures by many notable mathematicians and that the proof came from mathematical tools and methods which are far ahead of Fermat's time, this has led many to doubt that Fermat actually did possess the 'truly marvellous' proof which he claimed to have had. In this short reading, *via* elementary arithmetic methods which make use of Pythagoras theorem, we demonstrate conclusively that Fermat's Last Theorem actually yields to our efforts to prove it. This proof is so elementary that anyone with a modicum of mathematical prowess in Fermat's days and in the intervening 358 years could have discovered this very proof. This brings us to the tentative conclusion that Fermat might very well have had the 'truly marvellous' proof which he claimed to have had and his 'truly marvellous' proof may very well have made use of elementary arithmetic methods.

Keywords: Fermat's Last Theorem, Proof, Pythagoras theorem, Pythagorean triples.

*"Subtle is the Lord.
Malicious He is not."*

Albert Einstein (1879 – 1955).

1. Introduction

The pre-eminent French lawyer and amateur mathematician, Pierre de Fermat (1607 – 1665) in 1637, famously in the margin of a copy of the famous book *Arithmetica*, he wrote:

"It is impossible to separate a cube into two cubes, or a fourth power into two fourth powers, or in general, any power higher than the second, into two like powers. I have discovered a truly marvellous proof of this, which this margin is too narrow to contain."

In the parlance of mathematical symbolism, this can be written succinctly as:

$$\nexists (x, y, z, n) \in \mathbb{N}^+ : x^n + y^n = z^n \text{ for } (n > 2), \quad (1)$$

where the triple $(x, y, z) \neq 0$, is piecewise coprime, and \mathbb{N}^+ is the set of all positive integer numbers. This theorem is classified among the most famous theorems in all History of Mathematics and prior to 1995, proving it was –

and is; ranked in the *Guinness Book of World Records* as one of the "most difficult mathematical problems" known to humanity. Fermat's Last Theorem is now a true theorem since it has been proved, but prior to 1995 it was only a *conjecture*. Before it was proved in 1995, it is only for historic reasons that it was known by the title "*Fermat's Last Theorem*".

Rather notoriously, it stood as an unsolved riddle in mathematics for well over three and half centuries. Many amateur and great mathematicians tried but failed to prove the conjecture in the intervening years 1637 – 1995; including three of the World's greatest mathematicians such as Italy's Leonhard Euler (1707 – 1783), France's Pierre-Simon, marquis de Laplace (1749 – 1827), and the celebrated genius and Crown Prince of Mathematics, Germany's Johann Carl Friedrich Gauss (1777 – 1855), amongst many other notable and historic figures of mathematics.

Without any doubt, the conjecture or Fermat's Last Theorem is in-itself – as it stands as a bare statement, deceptively simple mathematical statement which any agile

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10 year old mathematical prodigy can fathom with relative ease. Fermat famously – *via* his bare marginal note; stated he had solved the riddle around 1637. His claim was discovered some 30 years later, after his death in 1665, as an overly simple statement in the margin of the famous copy *Arithmetica*. Fermat wrote many notes in the margins and most of these notes were ‘theorems’ he claimed to solved himself. Some of the proofs of his assertions were found. For those that were not found, all the proofs save for one resisted all intellectually spirited efforts to prove it and this was the marginal note pertaining the so-called Fermat’s Last Theorem.

This marginal note dubbed Fermat’s Last Theorem, was the last of the assertions made by Fermat whose proof was needed, and for this reason that it was the last of Fermat’s statement that stood unproven, it naturally found itself under the title ‘Fermat’s Last Theorem’. Because all of the many of Fermat’s assertions were eventually proved, most people believed that this last assertion must – too; be correct as Fermat had claimed. Few – if any; doubted the assertion may be false, hence the confidence to call it a theorem. Simple, the proof Fermat claimed to have had, had to be found!

Did Fermat actually possess the so-called ‘truly marvellous’ proof which he claimed to have had? This is the question many have justly and rightly asked over the years and this reading makes the temerarious endeavour to vindicate Fermat, that he very well might have had the ‘truly marvellous’ proof he claimed to have had and this we accomplish by providing a proof that employs elementary arithmetic methods that were available in Fermat’s day.

Surely, there are just reasons to doubt Fermat actually had the proof and this is so given the great many notable mathematicians that tried and monumentally failed and as well, given the number of years it took to find the first correct proof. The first correct proof was supplied only 358 years later by the English Professor of mathematics at the University of Cambridge – Sir Andrew John Wiles (1953–), in 1995 [1].

To add salt to injury *i.e.* add onto the doubts on whether or not Fermat actually had his so-called ‘truly marvellous’ proof is that Sir Professor Andrew Wiles’s proof* employs highly advanced mathematical tools and methods that were not at all available in the known World during Fermat’s days. Actually, these tools and methods were invented (discovered) in the relentless effort to solve this very problem. Herein, we supply a very simple proof of Fermat’s Last Theorem.

That said, we must hasten to say that, as a difficult mathematical problem that so far yielded only to the difficult, esoteric and advanced mathematical tools and methods of Sir Professor Andrew Wiles – Fermat’s Last Theorem, as any other difficult mathematical problem in the History of Mathematics, it has had a record number of in-

correct proofs of which the present may very well be an addition to this long list of incorrect proofs. In the words of historian of mathematics – Howard Eves [2]:

“Fermat’s Last Theorem has the peculiar distinction of being the mathematical problem for which the greatest number of incorrect proofs have been published.”

With that in mind, allow us to say, we are confident the proof we supply herein is water-tight and most certainly correct and that, it will stand the test of time and experience.

As stated in the *ante penultimate* above is that, in this rather short reading, we make the temerarious endeavour to answer this question – of whether or not Fermat actually possessed the proof he claimed to have had. This we accomplish by supplying a simple and elementary proof that does not require any advanced mathematics but mathematics that was available in the days of Fermat. Sir Professor Andrew Wiles’s acclaimed proof, is at best very difficult and to the chagrin of they that seek a simpler understanding – the proof is nothing but highly esoteric. The question thus ‘forever’ hangs in there to the searching and inquisitive mind: *“Did Fermat really possess the proof he claimed to have had?”* The proof that we supply herein leads us to strongly believe that Fermat might have had the proof and this proof most certainly employed elementary methods of arithmetics!

2. Proof

The proof that we are going to provide is a proof by contradiction. We assume that the statement:

$$\exists (x, y, z, n) \in \mathbb{N}^+ : x^n + y^n = z^n, \text{ for } (n > 2), \quad (2)$$

to be true. The tripple (x, y, z) is piecewise *coprime*, the meaning of which is that the greatest common divisor [$\text{gcd}()$] of this triple or any arbitrary pair of the triple is unity. For our proof, we shall proceed in a general way to show that the statement (2) can never be true for $(n > 2)$. In our approach, we split the problem into two parts, *i.e.*:

1. **Case (I)** : This case proves for all powers of $(n > 2) \in \mathbb{E}^+$ where \mathbb{E}^+ is the set of all positive even integer numbers.
2. **Case (II)** : This case proves for all powers of $(n > 2) \in \mathbb{O}^+$ where \mathbb{O}^+ is the set of all positive odd integer numbers.

Since the set $(n > 2) \in \mathbb{N}^+$ contains only odd and even values of n , to prove that there does not exist an even and odd $(n > 2) \in \mathbb{N}^+$ that satisfies (2) is a proof that there

* The proof by Sir Professor Wiles is well over 100 pages long and consumed about seven years of his research time. For this notable achievement of solving Fermat’s Last Theorem, he was Knighted *Commander of the Order of the British Empire* in 2000 by Her Majesty Queen Elizabeth (II), and received many other honours around the World.

does not exist $(x, y, z, n) \in \mathbb{N}^+ : x^n + y^n = z^n$, ($n > 2$). This is a proof of the original statement (1).

Proof for the Case $n = (3, 4 \& 5)$

As is well known, the case for ($n = 3$), for all non-zero (x, y, z) and $(x, y, z) \in \mathbb{N}^+$, the equation $x^3 + y^3 = z^3$ has no solutions. This was first proved by the great Italian mathematician Leonhard Euler in 1770 [3], that is, 133 years after Fermat set into motion Fermat's Last Theorem. Euler used the technique of *infinite descent*. Euler's proof is not the only proof possible as other authors have published their independent proofs [see e.g. Refs. 4, 5, 6, 7, 8, amongst many others].

Fermat was the first to provide a proof for the case ($n = 4$) which stated that for all non-zero piecewise coprime triple $(x, y, z) \in \mathbb{N}^+$, the equation $x^4 + y^4 = z^4$ admits no solutions. This proof by Fermat is the only surviving proof of Fermat's Last Theorem and as is the case with Euler's proof for the case ($n = 3$), Fermat's proof makes use of the technique of infinite descent. Further, as is the case with Euler's proof for ($n = 3$), Fermat's proof is not the only proof possible as other authors have published their independent proofs [see e.g. Refs. 5, 6, 9, 10, 11, amongst many others]. Even after Sir Professor Andrew Wiles's 1995 breakthrough [1], researchers are still publishing variants of the proof for the case ($n = 4$) [see e.g. 12, 13, 14].

The case ($n = 5$) was first proved independently by the French mathematician Adrien-Marie Legendre (1752 - 1833) and the German mathematician Johann Peter Gustav Lejeune Dirichlet (1805 - 1859) around 1825 and alternative and independent proofs were developed in the later years by others [see e.g. Refs. 5, 15, 16, 17, 18, 19, 20, 21, 22, amongst many others].

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Now, before we proceed to give our proof, we shall give a Lemma which is vital for path of the proof.

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Lemma 1: If $(a, b) \in \mathbb{N}^+$ such that:

$$a\sqrt{b} = c + d, \quad (3)$$

for some numbers (c, d) , then, insofar as whether or not \sqrt{b} is an integer or not, there are two conditions, and these are:

1. $\sqrt{b} \in \mathbb{N}^+$.
2. $\sqrt{b} \notin \mathbb{N}^+$. That is, \sqrt{b} is an irrational number.

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1. If, $\sqrt{b} \in \mathbb{N}^+$, then, $(c, d) \in \mathbb{N}^+$.

2. If, $\sqrt{b} \notin \mathbb{N}^+$, then \sqrt{b} is a surd – it is an irrational number and $(c, d) \notin \mathbb{N}^+$; and there must exist some $((c_1 < c) \& (d_1 < d)) \in \mathbb{N}^+$ such that $c = c_1\sqrt{b}$ and $d = d_1\sqrt{b}$ so that $a\sqrt{b} = c_1\sqrt{b} + d_1\sqrt{b}$, which implies that:

$$a = c_1 + d_1. \quad (4)$$

The above stated Lemma is a self evident truth which is not only necessary but vital and pivotal for the proof that we now give below.

2.1. Case (I): Even Powers of ($n > 2$)

If $(n > 2) \in \mathbb{E}^+$, then we can write $n = 2k$ where $k = 2, 3, 4, 5, \dots$ etc $\Rightarrow (k > 1)$. In this case, the equation $x^n + y^n = z^n$, will read:

$$x^{2k} + y^{2k} = z^{2k}, \quad (5)$$

and this can be rewritten as:

$$(x^k)^2 + (y^k)^2 = (z^k)^2. \quad (6)$$

The non-zero piecewise coprime numbers (x^k, y^k, z^k) are all integers, thus, the triple (x^k, y^k, z^k) , is a Pythagorean triple in the true sense of a Pythagorean triple. As is well known from Euclid's formula for generating primitive Pythagorean triples, if (p^k, q^k) are any arbitrary integers i.e. $(p, q : p > q) \in \mathbb{N}^+$ such that p^k and q^k are coprime and $p^k - q^k$ is odd, the triple (x^k, y^k, z^k) is such that:

$$\begin{pmatrix} x^k \\ y^k \\ z^k \end{pmatrix} = \begin{pmatrix} p^{2k} - q^{2k} \\ 2p^k q^k \\ p^{2k} + q^{2k} \end{pmatrix}. \quad (7)$$

Proof for the above is that:

$$\begin{aligned} (z^k)^2 &= (x^k)^2 + (y^k)^2 \\ \downarrow &\quad \quad \quad \downarrow \quad \quad \quad \downarrow \\ (p^{2k} + q^{2k})^2 &\equiv (p^{2k} - q^{2k})^2 + (2p^k q^k)^2 \end{aligned} \quad (8)$$

Now, for our proof, we simple need to take the y -component of (7) i.e. $y^k = 2p^k q^k$ which implies that $y = \sqrt[k]{2}pq$. Since $y \in \mathbb{N}^+$, it follows from $y = \sqrt[k]{2}pq$, that for $y \in \mathbb{N}^+$, $\sqrt[k]{2} \in \mathbb{N}^+$. We all know that for $\sqrt[k]{2} \in \mathbb{N}^+$, this is only so when $k = 1$. Since $(k > 2)$, it follows that there is no solution to the equation (7) for $(x, y, z) \in \mathbb{N}^+$ and $(k > 2)$. Since we have no solution to equation (7), it follows that (6) has no solutions too, hence (2) has no integer solutions for all non-zero piecewise coprime (x, y, z) for all powers of $(n > 2) \in \mathbb{E}^+$.

Q.E.D.

2.2. Case (II): Odd Powers of ($n > 2$)

Now, we have to prove for the case were $(n > 2) \in \mathbb{O}^+$. As before, we are going to employ Pythagoras theorem. We begin by rewriting $x^{2k+1} + y^{2k+1} = z^{2k+1}$ as:

$$(x^k \sqrt{x})^2 + (y^k \sqrt{y})^2 = (z^k \sqrt{z})^2. \quad (9)$$

The fact that $(n > 2) \in \mathbb{O}^+$, this implies that we can set $n = 2k + 1$ where $k = 1, 2, 3, 4, 5, \dots, etc \Rightarrow (k > 2)$. The triplet, trio or the three numbers $(x^k \sqrt{x}, y^k \sqrt{y}, z^k \sqrt{z})$ are not necessarily integers, thus this triple is not a Pythagorean triple in the traditional parlance of mathematics. However, this handicap does not stop us (or anyone for that matter) from finding real and irrational numbers $(p^{2k+1}, q^{2k+1} : p > q)$ which are not necessarily integers, where these numbers (p, q^{2k+1}) are such that:

$$\begin{pmatrix} x^k \sqrt{x} \\ y^k \sqrt{y} \\ z^k \sqrt{z} \end{pmatrix} = \begin{pmatrix} p^{4k+2} - q^{4k+2} \\ 2p^{2k+1}q^{2k+1} \\ p^{4k+2} + q^{4k+2} \end{pmatrix}. \quad (10)$$

As in equation (8), the proof for the above is that:

$$\begin{aligned} (z^k \sqrt{z})^2 &= (x^k \sqrt{x})^2 + (y^k \sqrt{y})^2 \\ \Downarrow & \qquad \qquad \qquad \Downarrow \qquad \qquad \qquad \Downarrow \\ (p^{4k+2} + q^{4k+2})^2 &\equiv (p^{4k+2} - q^{4k+2})^2 + (2p^{2k+1}q^{2k+1})^2 \end{aligned} \quad (11)$$

We are now going to look at the z -component of equation (10). For \sqrt{z} , we have two and only two cases (conditions) and these are:

1. $\sqrt{z} \in \mathbb{N}^+$.
2. $\sqrt{z} \notin \mathbb{N}^+$, is an irrational number.

In case (1) where $\sqrt{z} = w \in \mathbb{N}^+$, it follows that $(p, q) \in \mathbb{N}^+$. If $(p, q) \in \mathbb{N}^+$, it follows that $(\sqrt{x}, \sqrt{y}) \in \mathbb{N}^+$. Let $\sqrt{x} = u$ and $\sqrt{y} = v$, we will have:

$$\begin{pmatrix} u^{2k+1} \\ v^{2k+1} \\ w^{2k+1} \end{pmatrix} = \begin{pmatrix} p^{4k+2} - q^{4k+2} \\ 2p^{2k+1}q^{2k+1} \\ p^{4k+2} + q^{4k+2} \end{pmatrix}. \quad (12)$$

Now, as before, we take the y -component of (12) *i.e.* $v^{2k+1} = 2p^{2k+1}q^{2k+1}$. From this equation, it follows that $v = {}^{2k+1}\sqrt{2}pq$. We know that $v \in \mathbb{N}^+$. For this to be so, ${}^{2k+1}\sqrt{2} \in \mathbb{N}^+$ and the only way for this to be so is if $(2k + 1 = 1) \Rightarrow (k = 0)$. But in our case, we have $(k > 1) \in \mathbb{N}^+$.

In case (2) where $\sqrt{z} \notin \mathbb{N}^+$ is an irrational number, it follows from Lemma (1) that for the z -component of the equation (10), there must exist some $(a, b : a > b) \in \mathbb{N}^+$, such that $p^{4k+2} = a\sqrt{z}$ and $q^{4k+2} = b\sqrt{z}$ *i.e.*, $z^k \sqrt{z} = a\sqrt{z} + b\sqrt{z}$. From $p^{4k+2} = a\sqrt{z}$ and $q^{4k+2} = b\sqrt{z}$ it follows that $p^{2k+1} = \sqrt{a\sqrt{z}}$ and $q^{2k+1} = \sqrt{b\sqrt{z}}$. Substituting all this into (10), we will have:

$$\begin{pmatrix} x^k \sqrt{x} \\ y^k \sqrt{y} \\ z^k \sqrt{z} \end{pmatrix} = \begin{pmatrix} (a - b)\sqrt{z} \\ 2\sqrt{a}\sqrt{b}\sqrt{z} \\ (a + b)\sqrt{z} \end{pmatrix}. \quad (13)$$

What does equation (13) as a whole mean? Well, we know that $x^k \in \mathbb{N}^+$ but (13) is telling us that $x^k = (a - b)\sqrt{z/x}$. Since $(a - b) \in \mathbb{N}^+$, for $x^k = (a - b)\sqrt{z/x} \in \mathbb{N}^+$, $\sqrt{z/x} = s \in \mathbb{N}^+$ *i.e.* $z = s^2x$. This means that x and z share a common factor s^2 , the meaning of which is that the triple (x, y, z) is not piecewise coprime. Since our initial assertion runs contrary to our final conclusion, hence, by way of contradiction, it follows that our initial assertion is wrong as it has lead us to an illogical conclusion. Hence, (2) has no integer solutions for all non-zero piecewise coprime triple (x, y, z) for all powers of $(n > 2) \in \mathbb{O}^+$.

Q.E.D.

2.3. Summary of the Two Proofs

In §(2.1.) and (2.2.), we have proved that (2) has no integer solutions for any $(x, y, z) > 0$ and $(x, y, z) \in \mathbb{N}^+$ for all powers of $(n > 2) \in \mathbb{E}^+$ and for all powers $(n > 2) \in \mathbb{O}^+$. Combining these two proofs, it follows from the foregoing as stated and outlined at the beginning of this section, that (2) has no integer solutions for any $(x, y, z) > 0$ and $(x, y, z) \in \mathbb{N}^+$ for all powers of $(n > 2) \in \mathbb{N}^+$. Hence Fermat's Last Theorem is here proved in a simpler, much more general and truly marvellous manner.

Q.E.D.

3. Discussion and Conclusion

If the proof we have provided herein stands the test of time and experience, then, it is without a doubt that Fermat's claim to have had a 'truly marvellous' proof may very well resonate with truth. If this proof employed the use of Pythagoras theorem as in the present case, then, for any book, the standard 'margin is too narrow' to contain the present proof, the meaning of which is that Fermat was most certainly right in his famous claim.

Clearly, the problem with the proof is not that it is difficult and only accessible to the highly esoteric, no! We ourselves (*i.e.*, amateur and seasoned mathematicians alike) have made this problem appear very difficult, highly esoteric and only accessible to foremost and advanced mathematical minds. Without the historic and personal encodes that will soon follow, this proof (*i.e.*, the morass substance of the present reading) can be typed using a standard font size of between 10 – 12, *back-to-back* on a single standard a4-page. Few – if any; would believe that this is possible. The level difficulty and esoteric nature associated with this problem has been – until the present reading, very high.

What could have happened leading to the elevation of this problem to a point where it came to become one of

the most difficult problems in all History of Mathematics is that – perhaps; the plethora of maiden failures to provide a proof must have led people to think that this problem must be very difficult. Failure after failure and especially so by great mathematicians must then have led to it [Fermat’s Last Theorem] achieving ‘international, worldwide and historic notoriety’ as a very difficult problem that eluded even great minds like Euler, Laplace and Gauss. With this kind of background, certainly, when people approached this problem, they most probably did so with in mind that it was a very difficult problem probably to be solved by ‘real super geniuses’ and not mortals of modest means *e.g.* ourself.

If someone told you that a given problem is so difficult, so much that it has thus far eluded the finest, advanced and most esoteric minds that have attempted to find its solution, one naturally tries to use higher advanced methods to prove it. Further, if someone told you that a given problem is so difficult, so much that it have eluded the finest, advanced and most esoteric minds that have attempted to find its solution, one naturally is discouraged from using simple elementary methods to prove it because the feeling one has is that, if it can be solved *via* a simple method, surely, advanced minds before me must have discovered this, thus leading one to try and climb higher than those before them. If what we have presented stands the test of time and experience, then, the way we approach difficult problems may need recourse, especially the way the public media projects and posts the level difficulty and the supposed esoteric effort required in-order to solve these problems.

Our approach to solving so-called outstanding problems is that one must not be let down by the public media projections of the level difficult and the supposed esoteric effort required in-order to solve the problem. First, as we climb the ladder of level difficulty, we tackle it [problem] from a level simplicity accessible to the ‘layman’ and step-by-step as we move up the ladder. To us, we have come to realise that this has helped us in understanding the problem at a much deeper level. At each level, we make sure we exhaust ‘all’ the possible avenues. As to how one knows they have exhausted all the possible avenues, this is a difficult question to answer but the most potent and virile tool for us has been a deep and strong inner intuition, unshakable confidence in the solubility of the problem and singular conviction that victory is certain if one persists.

As we anxiously await the World to judge our proof, effort and work, we must — if this be permitted at this point of closing, say that, we are confident that – simple as it is or may appear, this proof is flawless, it will stand the test of time and experience. It strongly appears that the great physicist and philosopher – Albeit Einstein (1879 – 1955), was probably right in saying that “*Subtle is the Lord. Malicious He is not.*” because in Lemma (1), there exists deeply embedded therein, a subtlety that resolves and does away with the malice and notoriety associated with Fermat’s Last Theorem in a simpler and

truly marvellous and general manner.

Conclusion

We hereby make the following conclusion:

1. By use of the method of ‘Pythagorean triples’, we have demonstrated that a solution to Fermat’s Last Theorem exists in the realm of elementary arithmetic.
2. This proof employs elementary arithmetic tools and methods that were certainly accessible to Fermat, thus making it highly likely that Fermat’s claim that he possessed a ‘truly marvellous’ proof may very be true.
3. From the proof we have given, three generalizations can be made and these are:
 - (a) If (x, y, z) is a primitive Pythagorean triple, then, the triple $(\sqrt[n]{x}, \sqrt[n]{y}, \sqrt[n]{z}) \in \mathbb{N}^+$ can never be such that $(\sqrt[n]{x}, \sqrt[n]{y}, \sqrt[n]{z}) \notin \mathbb{N}^+$ for any $(n > 1) \in \mathbb{N}^+$.
 - (b) If (x, y, z) is a non-zero piecewise coprime triple, then, the equations:

$$z^n = x^{2n} - y^{2n}, \quad (14)$$

$$z^n = x^{2n} + y^{2n}, \quad (15)$$

have no solutions for $(n > 1) \in \mathbb{N}^+$.

3.1. After Thought

Looking at Fermat’s Last Theorem, it appears as though the number of terms which are added to obtain z^n in (1) may need to be increased in-order for there to be a solution. We thus wonder if there is in a general minimum $(m > 2) \in \mathbb{N}^+$ for any $(n > 2) \in \mathbb{N}^+$ such that the equation:

$$y_n = \sum_{k=1}^m x_k^n, \quad (16)$$

has a solution for some non-zero piecewise coprime set $(y, x_k : k > 2) \in \mathbb{N}^+$.

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