

The idea of the Arithmetica

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Abstract

During the 360 years of Fermat's last theorem is to be proved, this proposition was the presence appear full-length novel in "The Lord of the Rings", such as the "One Ring". And finally in 1994, it was proved completely by Andrew Wiles. However interesting proof is Fermat has been is still unknown. This will be assumed in the category of algebra probably.

introduction

Natural number X,Y and Z solution of 3 or more that this equation holds $X^n + Y^n = Z^n$ does not exist. Fermat is proven for the conditions of $n = 4$. It is sufficient if n is examining the conditions of prime numbers greater than or equal to 3 for this.

Theorem 1 *Triangle the hypotenuse of Pythagorean theorem is z , can be expressed by the following relation by using the l and m .*

$$(l^2 - m^2)^2 + 2^2 (lm)^2 = (l^2 + m^2)^2$$

$$x^2 = (l^2 - m^2)^2$$

$$y^2 = 2^2 (lm)^2$$

$$z^2 = (l^2 + m^2)^2$$

$$(xyz \neq 0)$$

To simplify the algebra as a real number M, and N.

$$M, N \in \mathbb{R} \quad l^2 = M, \quad m^2 = N$$

$$(M - N)^2 + 2^2 MN = (M + N)^2$$

Put $X, Y, Z \in \mathbb{N}$ *prime number* = $p \geq 3$

$$\begin{aligned} X^p &= (M - N)^2 \\ Y^p &= 2^2 MN \\ Z^p &= (M + N)^2 \end{aligned}$$

$(XYZ \neq 0)$

Add the following conditions. $X, Y, Z \in$ *even number*

$$\begin{aligned} X^p &= 2^p X_1^p \\ Y^p &= 2^p Y_1^p \\ Z^p &= 2^p Z_1^p \\ (X_1, Y_1, Z_1 &\in \mathbb{N}) \end{aligned}$$

$$MN = 2^{p-2} Y_1^p \in \mathbb{N}$$

Thus M, N is a rational or irrational both.

1 M, N is a condition of both rational

$$X^p = 2^p X_1^p, \quad Z^p = 2^p Z_1^p$$

$M - N, M + N \in$ *even number*, and it will be a divisor of $2^{\frac{p+1}{2}}$ at least.

Consequently, $Y_1^p \in$ *even number* so $X_1^p, Z_1^p \in$ *even number*. (1)

2 M, N is a condition of both irrational

$$\begin{aligned} MN &= 2^{p-2} Y_1^p \\ &= 2^{p-2} (Z_1^p - X_1^p) \\ &= 2^{p-2} \left(\sqrt{Z_1^p} + \sqrt{X_1^p} \right) \left(\sqrt{Z_1^p} - \sqrt{X_1^p} \right) \end{aligned}$$

$$X^p = 2^p X_1^p, \quad Z^p = 2^p Z_1^p$$

$$M = \left(\sqrt{2^{p-2} Z_1^p} + \sqrt{2^{p-2} X_1^p} \right) \quad N = \left(\sqrt{2^{p-2} Z_1^p} - \sqrt{2^{p-2} X_1^p} \right) \quad (M > N)$$

$$\begin{aligned} \text{Put } (c, d \in \text{odd number} \quad l, m \in \mathbb{N}) \\ M = 2^{\frac{l}{2}} c^{\frac{1}{2}} + 2^{\frac{m}{2}} d^{\frac{1}{2}} \quad N = 2^{\frac{l}{2}} c^{\frac{1}{2}} - 2^{\frac{m}{2}} d^{\frac{1}{2}} \end{aligned} \quad (\text{I})$$

In addition, assuming that there is no difference and sum,

$$\begin{aligned} &\text{Put}(U, V \in \text{odd number}) \\ M = 2^{\frac{l}{2}}U & \qquad N = 2^{\frac{m}{2}}V \end{aligned} \quad (\text{II})$$

$$MN = 2^{p-2}Y_1^p = 2^{\frac{l+m}{2}}UV \in \mathbb{N}$$

M, N because irrational both, therefore $(l, m \in \text{odd number})$.

2.1 Conditions of (II)

2.1.1 Conditions of $(Y_1^p \in \text{odd number})$

$$Y_1^p = Z_1^p - X_1^p$$

Z_1^p, X_1^p is the relationship of "odd and even" or "odd and even".

Z_1^p and X_1^p are assumed to be coprime. Common divisor R^p ($\in \text{odd number}$), if present in the Z_1^p and X_1^p , is included as a common divisor of R^p also Y_1^p .
 $(\frac{Y_1^p}{R^p} \in \mathbb{N})$

It is possible to remove common divisor, it is sufficient Z_1^p and X_1^p is examining the conditions of coprime.

$$MN = 2^{p-2}Y_1^p = 2^{\frac{l+m}{2}}UV \quad (p = \frac{l+m}{2} + 2 \quad Y_1^p = UV)$$

Proposition 2 $l > m \quad \frac{l+m}{2} > m$ ($l, m \in \text{odd number} \quad U, V \in \text{odd number}$)

$$\underline{\text{odd number} = 2^{\frac{l-m}{2}+2}X_1^p}$$

$$\begin{aligned} X^p &= (M - N)^2 \\ &= M^2 + N^2 - 2MN \\ &= 2^l U^2 + 2^m V^2 - 2 \cdot 2^{\frac{l+m}{2}} UV \\ &= 2^m \left(2^{l-m} U^2 + V^2 - 2 \cdot 2^{\frac{l-m}{2}} UV \right) \\ &= 2^m (\text{odd number}) \end{aligned}$$

$$X^p = 2^m \left(2^{\frac{l-m}{2}+2} X_1^p \right)$$

$$\text{odd number} \neq 2^{\frac{l-m}{2}+2} X_1^p \quad (2)$$

Lemma 3 $l = p - 2 \quad m = p - 2$ ($l, m \in \text{odd number} \quad U, V \in \text{odd number}$)

Other things being does not hold all applies the infinite descent.

$$X^p = (M - N)^2 = \left(2^{\frac{p-2}{2}}U - 2^{\frac{p-2}{2}}V\right)^2 = 2^{p-2} (U - V)^2$$

$$\begin{aligned} 2^2 X_1^p &= (U - V)^2 & (U > V) \\ 2\sqrt{X_1^p} &= U - V & \cdots\textcircled{1} \end{aligned}$$

$$Z^p = (M + N)^2 = \left(2^{\frac{p-2}{2}}U + 2^{\frac{p-2}{2}}V\right)^2 = 2^{p-2} (U + V)^2$$

$$\begin{aligned} 2^2 Z_1^p &= (U + V)^2 & (U > V) \\ 2\sqrt{Z_1^p} &= U + V & \cdots\textcircled{2} \end{aligned}$$

X_1^p, Z_1^p is a square number $U \pm V$ because it is a natural number.

$$X_1^p = (X_{II}^p)^2 \quad Z_1^p = (Z_{II}^p)^2 \quad (X_{II}^p, Z_{II}^p \in \mathbb{N})$$

simultaneous equation: $\textcircled{1} \pm \textcircled{2}$

$$U = Z_{II}^p + X_{II}^p \quad V = Z_{II}^p - X_{II}^p$$

If U, V is not a coprime, and a common divisor r (\in odd number).

$$U = Z_{II}^p + X_{II}^p = rf \quad \cdots\textcircled{3}$$

$$V = Z_{II}^p - X_{II}^p = rg \quad \cdots\textcircled{4}$$

$$(U, V \in \text{odd number} \quad f, g \in \text{odd number})$$

simultaneous equation: $\textcircled{3} \pm \textcircled{4}$

$$2Z_{II}^p = r(f + g)$$

$$2X_{II}^p = r(f - g)$$

X_{II}^p, Z_{II}^p comprises a common divisor r . but X_{II}^p, Z_{II}^p must also be coprime X_1^p, Z_1^p is coprime. Thus U, V is coprime.

Theorem 4 ($Y_1^p = UV$) U, V is at a coprime, which is a power of a prime number.

$$U = U_{II}^p, \quad V = V_{II}^p \quad Y_1^p = (U_{II}V_{II})^p$$

Substitute U_{II}^p, V_{II}^p for $\textcircled{3}, \textcircled{4}$.

$$U_{II}^p = Z_{II}^p + X_{II}^p \quad V_{II}^p + X_{II}^p = Z_{II}^p \quad (3)$$

2.1.2 Conditions of ($Y_1^p \in \text{even number}$)

($Y^p = 2^2 MN$) MN because it has a divisor in 2^{2p-2} at least,

$$\frac{l+m}{2} \geq 2p-2 \quad M = 2^{\frac{l}{2}} U, \quad N = 2^{\frac{m}{2}} V \quad (U, V \in \text{odd number})$$

Proposition 5 $p > m$ $(l+m \geq 2(2p-2))$ $l > m$ $l, m \in \text{odd number}$

$$\underline{\text{odd number} = 2^{p-m} X_1^p}$$

$$\begin{aligned} X^p &= (M - N)^2 \\ &= M^2 + N^2 - 2MN \\ &= 2^l U^2 + 2^m V^2 - 2 \cdot 2^{\frac{l+m}{2}} UV \\ &= 2^m \left(2^{l-m} U^2 + V^2 - 2 \cdot 2^{\frac{l-m}{2}} UV \right) \\ &= 2^m (\text{odd number}) \end{aligned}$$

$$X^p = 2^p X_1^p = 2^m (2^{p-m} X_1^p)$$

$$\underline{\text{odd number} \neq 2^{p-m} X_1^p} \tag{4}$$

Proposition 6 $p = m$ $(l+m \geq 2(2p-2))$ $l > m$ $l, m \in \text{odd number}$

$$\underline{V \neq N}$$

$$\begin{aligned} l+p &\geq 2(2p-2) \\ l &\geq 2(2p-2) - p \end{aligned}$$

($l, p \in \text{odd number}$ $q \in \text{even number}$)

$$\begin{aligned} l &= 2(2p-2) - p + q \\ l &= 4(p-1) - p + q \end{aligned}$$

$$\begin{aligned} X^p &= (M - N)^2 \\ &= M^2 + N^2 - 2MN \\ &= 2^l U^2 + 2^m V^2 - 2 \cdot 2^{\frac{l+m}{2}} UV \\ &= 2^{4(p-1)-p+q} U^2 + 2^p V^2 - 2 \cdot 2^{2(p-1)+\frac{q}{2}} UV \\ &= 2^p \left(2^{4(p-1)-2p+q} U^2 + V^2 - 2 \cdot 2^{2(p-1)-p+\frac{q}{2}} UV \right) \\ &= 2^p \left(\left(2^{2(p-1)-p+\frac{q}{2}} U \right)^2 + V^2 - 2 \cdot 2^{2(p-1)-p+\frac{q}{2}} UV \right) \\ &= 2^p \left(2^{p-2+\frac{q}{2}} U - V \right)^2 \\ &= 2^p X_1^p \\ X_1^p &= \left(2^{p-2+\frac{q}{2}} U - V \right)^2 \end{aligned}$$

Similarly,

$$\begin{aligned} Z^p &= 2^p \left(2^{p-2+\frac{q}{2}}U + V \right)^2 \\ &= 2^p Z_1^p \\ Z_1^p &= \left(2^{p-2+\frac{q}{2}}U + V \right)^2 \end{aligned}$$

X_1^p, Z_1^p is a square number $2^{p-2+\frac{q}{2}}U + V$ because it is a natural number.

$$X_1^p = (X_{II}^p)^2, \quad Z_1^p = (Z_{II}^p)^2 \quad (X_{II}^p, Z_{II}^p \in \mathbb{N})$$

$$Z_{II}^p = 2^{p-2+\frac{q}{2}}U + V \quad \dots \textcircled{5}$$

$$X_{II}^p = 2^{p-2+\frac{q}{2}}U - V \quad \dots \textcircled{6}$$

simultaneous equation: $\textcircled{5} + \textcircled{6}$

$$X_{II}^p + Z_{II}^p = 2^{p-1+\frac{q}{2}}U$$

Corollary 7 $(a+b)^2 + (a-b)^2 = 2(a^2 + b^2)$: *The sum of the squares of two*

$$(a, b \in \mathbb{R} \quad a > b)$$

And multiplied by 2^{p-2} to both sides.

$$2^{p-2}(a+b)^2 + 2^{p-2}(a-b)^2 = 2^{p-1}(a^2 + b^2)$$

$$\begin{aligned} Z_{II}^p &= 2^{p-2}(a+b)^2 && (Z_{II}^p > X_{II}^p) \\ X_{II}^p &= 2^{p-2}(a-b)^2 \\ 2^{p-1+\frac{q}{2}}U &= 2^{p-1}(a^2 + b^2) \end{aligned}$$

$$\begin{aligned} Z_{II}^p &= 2^{p-2}(a^2 + b^2 + 2ab) \\ X_{II}^p &= 2^{p-2}(a^2 + b^2 - 2ab) \\ 2^{\frac{q}{2}}U &= a^2 + b^2 \end{aligned}$$

$$\begin{aligned} Z_{II}^p &= 2^{p-2} \left(2^{\frac{q}{2}}U + 2ab \right) = 2^{p-2+\frac{q}{2}}U + 2^{p-1}ab \\ X_{II}^p &= 2^{p-2} \left(2^{\frac{q}{2}}U - 2ab \right) = 2^{p-2+\frac{q}{2}}U - 2^{p-1}ab \end{aligned}$$

In comparison with $\textcircled{5}, \textcircled{6}$.

$$\begin{aligned} 2^{p-1}ab &= V \\ ab &= \frac{V}{2^{p-1}} \end{aligned}$$

$$\begin{cases} a = \frac{V}{2^{p-1}b} \\ b = \frac{V}{2^{p-1}a} \end{cases}$$

Squaring both sides.

$$\begin{cases} a^2 = \left(\frac{V}{2^{p-1}b}\right)^2 \\ b^2 = \left(\frac{V}{2^{p-1}a}\right)^2 \end{cases}$$

$$a^2 + b^2 = 2^{\frac{q}{2}}U$$

$$\begin{cases} \left(\frac{V}{2^{p-1}a}\right)^2 + a^2 = 2^{\frac{q}{2}}U \\ \left(\frac{V}{2^{p-1}b}\right)^2 + b^2 = 2^{\frac{q}{2}}U \end{cases}$$

Corollary 8 $(s+t)^2 + (s-t)^2 = 2(s^2 + t^2)$: *The sum of the squares of two*

$$(s, t \in \mathbb{R} \quad s > t)$$

$$\left(\frac{V}{2^{p-1}b}\right)^2 + b^2 = 2^{\frac{q}{2}}U$$

Put $b = s \mp t \quad \frac{V}{2^{p-1}b} = s \pm t \quad 2^{\frac{q}{2}}U = 2(s^2 + t^2)$

$$\frac{V}{2^{p-1}(s \mp t)} = s \pm t \quad (s \neq t)$$

$$\frac{V}{2^{p-1}} = s^2 - t^2 \quad \cdots \textcircled{7} \quad \text{Was added to } 2t^2 \text{ to both sides.}$$

$$\frac{V}{2^{p-1}} + 2t^2 = s^2 + t^2 \quad \text{And multiplied by 2 to both sides.}$$

$$\frac{V}{2^{p-2}} + (2t)^2 = 2^{\frac{q}{2}}U \quad \cdots \textcircled{8}$$

Put $a = 2^{\frac{1}{2}}s \quad b = 2^{\frac{1}{2}}t \quad \text{or}(a = 2^{\frac{1}{2}}t \quad b = 2^{\frac{1}{2}}s)$

$$s + t = 2^{\frac{1}{2}}s \quad \cdots \textcircled{9}$$

$$s - t = 2^{\frac{1}{2}}t \quad \cdots \textcircled{10}$$

simultaneous equation: $\textcircled{9} \pm \textcircled{10}$

$$2s = 2^{\frac{1}{2}}s + 2^{\frac{1}{2}}t$$

$$s = 2^{-\frac{1}{2}}s + 2^{-\frac{1}{2}}t$$

$$2t = 2^{\frac{1}{2}}s - 2^{\frac{1}{2}}t$$

$$t = 2^{-\frac{1}{2}}s - 2^{-\frac{1}{2}}t$$

$$\begin{aligned}
s &= 2^{-\frac{1}{2}}s + 2^{-\frac{1}{2}}t \\
s - 2^{-\frac{1}{2}}s &= 2^{-\frac{1}{2}}t \\
(1 - 2^{-\frac{1}{2}})s &= 2^{-\frac{1}{2}}t \\
s &= 2^{-\frac{1}{2}}t(1 - 2^{-\frac{1}{2}})^{-1}
\end{aligned}$$

By referring to the ⑦.

$$\begin{aligned}
\frac{V}{2^{p-1}} &= s^2 - t^2 \\
&= \left(2^{-\frac{1}{2}}t(1 - 2^{-\frac{1}{2}})^{-1}\right)^2 - t^2 \\
&= 2^{-1}t^2(1 - 2^{-\frac{1}{2}})^{-2} - t^2 \\
&= 2^{-1}t^2(1 + 2^{-1} - 2^{\frac{1}{2}})^{-1} - t^2 \\
&= t^2(2 + 1 - 2^{\frac{3}{2}})^{-1} - t^2 \\
&= t^2\left(\left(3 - 2^{\frac{3}{2}}\right)^{-1} - 1\right) \quad \text{And multiplied by } 2^p \text{ to both sides.} \\
2V &= 2^p t^2 \left(\left(3 - 2^{\frac{3}{2}}\right)^{-1} - 1\right) \\
2V &= 2^p t^2 \left(\frac{1}{3 - 2\sqrt{2}} - 1\right)
\end{aligned}$$

By referring to the ⑧.

$$\begin{aligned}
\frac{V}{2^{p-2}} + (2t)^2 &= 2^{\frac{q}{2}}U \quad \text{And multiplied by } 2^{p-2} \text{ to both sides.} \\
V + 2^{p-2} \cdot 2^2 t^2 &= 2^{p-2+\frac{q}{2}}U \\
2^p t^2 &= 2^{p-2+\frac{q}{2}}U - V \in \mathbb{N} \quad (q \in \text{even number})
\end{aligned}$$

$$\begin{cases} a = \frac{V}{2^{p-1}b} & a = 2^{\frac{1}{2}}s \quad b = 2^{\frac{1}{2}}t \\ b = \frac{V}{2^{p-1}a} \end{cases}$$

In this condition, the relationship of the following equation is maintained.

$$ab = \frac{V}{2^{p-1}} \quad a^2 + b^2 = 2^{\frac{q}{2}}U$$

Therefore,

$$2V = 2^p t^2 \left(\frac{1}{3 - 2\sqrt{2}} - 1\right) \quad 2V \neq \mathbb{N} \quad (5)$$

Proposition 9 $p < m$ $(l + m \geq 2(2p - 2))$ $l \geq m$ $l > m$ $l, m \in \text{odd number}$

$X_1^p, Z_1^p \in \text{even number.}$

$$\begin{aligned} X^p &= (M - N)^2 \\ &= M^2 + N^2 - 2MN \\ &= 2^l U^2 + 2^m V^2 - 2 \cdot 2^{\frac{l+m}{2}} UV \\ &= 2^m \left(2^{l-m} U^2 + V^2 - 2 \cdot 2^{\frac{l-m}{2}} UV \right) \end{aligned}$$

Similarly,

$$\begin{aligned} Z^p &= (M + N)^2 \\ &= 2^l U^2 + 2^m V^2 + 2 \cdot 2^{\frac{l+m}{2}} UV \end{aligned}$$

$$p < m \quad \left(2^{l-m} U^2 + V^2 + 2 \cdot 2^{\frac{l-m}{2}} UV \right) \in \mathbb{N}$$

$$Y_1^p \in \text{even number so } X_1^p, Z_1^p \in \text{even number.} \quad (6)$$

2.2 Conditions of (I)

$$M = 2^{\frac{l}{2}} c^{\frac{1}{2}} + 2^{\frac{m}{2}} d^{\frac{1}{2}} \quad N = 2^{\frac{l}{2}} c^{\frac{1}{2}} - 2^{\frac{m}{2}} d^{\frac{1}{2}} \quad (c, d \in \text{odd number } l, m \in \mathbb{N})$$

$$\begin{aligned} X^p &= 2^p X_1^p = (M - N)^2 = \left(2 \cdot 2^{\frac{m}{2}} d^{\frac{1}{2}} \right)^2 = 2^2 2^m d \\ Z^p &= 2^p Z_1^p = (M + N)^2 = \left(2 \cdot 2^{\frac{l}{2}} c^{\frac{1}{2}} \right)^2 = 2^2 2^l c \end{aligned}$$

Corollary 10 $(a + b)^2 + (a - b)^2 = 2(a^2 + b^2)$: The sum of the squares of two

$$(a, b \in \mathbb{R} \quad a > b)$$

$$\begin{aligned} x^p &= (a + b)^2 \\ y^p &= (a - b)^2 \\ z^p &= 2(a^2 + b^2) \\ (xyz \neq 0) \end{aligned}$$

$$\begin{aligned}
X^p &= (M - N)^2 = (a + b)^2 \\
M - N &= a + b \\
\left(2 \cdot 2^{\frac{m}{2}} d^{\frac{1}{2}}\right)^2 &= (a + b)^2 \\
2^2 2^m d &= a^2 + b^2 + 2ab && \text{And multiplied by 2 to both sides.} \\
2^{m+3} d &= 2(a^2 + b^2) + 2^2 ab && (z^p = 2(a^2 + b^2)) \\
2^{m+3} d &= z^p + 2^2 ab \\
2^{m+3} d - 2^2 ab &= z^p && \dots \textcircled{11}
\end{aligned}$$

$$MN = 2^{p-2} Y_1^p = \left(2^{\frac{l}{2}} c^{\frac{1}{2}} + 2^{\frac{m}{2}} d^{\frac{1}{2}}\right) \left(2^{\frac{l}{2}} c^{\frac{1}{2}} - 2^{\frac{m}{2}} d^{\frac{1}{2}}\right) = 2^l c - 2^m d$$

$$\begin{aligned}
Y^p &= 2^p Y_1^p \\
Y^p &= 2^2 (2^l c - 2^m d) = (a - b)^2 \\
2^2 (2^l c - 2^m d) &= a^2 + b^2 - 2ab && \text{And multiplied by 2 to both sides.} \\
2^3 (2^l c - 2^m d) &= 2(a^2 + b^2) - 2^2 ab && (z^p = 2(a^2 + b^2)) \\
2^{l+3} c - 2^{m+3} d &= z^p - 2^2 ab \\
2^{l+3} c - 2^{m+3} d + 2^2 ab &= z^p && \dots \textcircled{12}
\end{aligned}$$

simultaneous equation: $\textcircled{12} - \textcircled{11}$

$$\begin{aligned}
2^{l+3} c - 2^{m+4} d + 2^3 ab &= 0 \\
2^l c - 2^{m+1} d + ab &= 0 \\
ab &= 2^{m+1} d - 2^l c
\end{aligned}$$

Remark 11 *Meanwhile, in an inverse relationship,*

$$\begin{aligned}
X^p &= (a - b)^2 \\
2^{m+3} d + 2^2 ab &= z^p && \dots \textcircled{13} \\
Y^p &= (a + b)^2 \\
2^{l+3} c - 2^{m+3} d - 2^2 ab &= z^p && \dots \textcircled{14}
\end{aligned}$$

simultaneous equation: $\textcircled{13} - \textcircled{14}$

$$\begin{aligned}
-2^{l+3} c + 2^{m+4} d + 2^3 ab &= 0 \\
-2^l c + 2^{m+1} d + ab &= 0 \\
ab &= 2^l c - 2^{m+1} d
\end{aligned}$$

$$\begin{aligned}
\text{put } 2^{m+1} d - 2^l c &= e \\
ab &= e
\end{aligned}$$

$$\begin{cases} a = \frac{e}{b} \\ b = \frac{e}{a} \end{cases}$$

Squaring both sides.

$$\begin{cases} a^2 = \left(\frac{e}{b}\right)^2 \\ b^2 = \left(\frac{e}{a}\right)^2 \end{cases}$$

$$a^2 + b^2 = \frac{z^p}{2}$$

$$\begin{cases} \left(\left(\frac{e}{a}\right)^2 + a^2\right) = \frac{z^p}{2} \\ \left(\left(\frac{e}{b}\right)^2 + b^2\right) = \frac{z^p}{2} \end{cases}$$

Corollary 12 $(s+t)^2 + (s-t)^2 = 2(s^2 + t^2)$: The sum of the squares of two

$$(s, t \in \mathbb{R} \quad s > t)$$

$$\left(\frac{e}{b}\right)^2 + b^2 = \frac{z^p}{2}$$

$$b = s \mp t \quad \frac{e}{b} = s \pm t \quad \frac{z^p}{2} = 2(s^2 + t^2)$$

$$\frac{e}{b} = s \pm t$$

$$\frac{e}{s \mp t} = s \pm t \quad (s \neq t)$$

$$e = s^2 - t^2 \quad \cdots \textcircled{15} \quad \text{Was added to } 2t^2 \text{ to both sides.}$$

$$e + 2t^2 = s^2 + t^2 \quad \text{And multiplied by 2 to both sides.}$$

$$2e + (2t)^2 = \frac{z^p}{2} \quad \cdots \textcircled{16}$$

$$\begin{cases} a = \frac{e}{b} & a = 2^{\frac{1}{2}}s \quad b = 2^{\frac{1}{2}}t \\ b = \frac{e}{a} \end{cases}$$

$$\text{Put } a = 2^{\frac{1}{2}}s \quad b = 2^{\frac{1}{2}}t \quad (\text{or } a = 2^{\frac{1}{2}}t \quad b = 2^{\frac{1}{2}}s)$$

$$s + t = 2^{\frac{1}{2}}s \quad \cdots \textcircled{17}$$

$$s - t = 2^{\frac{1}{2}}t \quad \cdots \textcircled{18}$$

simultaneous equation: $\textcircled{17} \pm \textcircled{18}$

$$2s = 2^{\frac{1}{2}}s + 2^{\frac{1}{2}}t$$

$$s = 2^{-\frac{1}{2}}s + 2^{-\frac{1}{2}}t$$

$$2t = 2^{\frac{1}{2}}s - 2^{\frac{1}{2}}t$$

$$t = 2^{-\frac{1}{2}}s - 2^{-\frac{1}{2}}t$$

$$\begin{aligned}
s &= 2^{-\frac{1}{2}}s + 2^{-\frac{1}{2}}t \\
s - 2^{-\frac{1}{2}}s &= 2^{-\frac{1}{2}}t \\
(1 - 2^{-\frac{1}{2}})s &= 2^{-\frac{1}{2}}t \\
s &= 2^{-\frac{1}{2}}t(1 - 2^{-\frac{1}{2}})^{-1}
\end{aligned}$$

By referring to the ⑮.

$$\begin{aligned}
e &= s^2 - t^2 \\
&= \left(2^{-\frac{1}{2}}t(1 - 2^{-\frac{1}{2}})^{-1}\right)^2 - t^2 \\
&= 2^{-1}t^2(1 - 2^{-\frac{1}{2}})^{-2} - t^2 \\
&= 2^{-1}t^2(1 + 2^{-1} - 2^{\frac{1}{2}})^{-1} - t^2 \\
&= t^2(2 + 1 - 2^{\frac{3}{2}})^{-1} - t^2 \\
&= t^2(3 - 2^{\frac{3}{2}})^{-1} - t^2 \\
&= t^2\left((3 - 2^{\frac{3}{2}})^{-1} - 1\right) \quad \text{And multiplied by } 2^2 \text{ to both sides.}
\end{aligned}$$

$$\left((3 - 2^{\frac{3}{2}})^{-1} - 1\right)^{-1} 2^2 e = 2^2 t^2 \quad \dots \textcircled{19}$$

By referring to the ⑯.

$$\begin{aligned}
2e + (2t)^2 &= \frac{z^p}{2} \quad \text{Substitute ⑱.} \\
2e + \left((3 - 2^{\frac{3}{2}})^{-1} - 1\right)^{-1} 2^2 e &= \frac{z^p}{2} \quad \text{And multiplied by } \frac{1}{2} \text{ to both sides.} \\
e + \left(\frac{2}{3 - 2\sqrt{2}} - 2\right) e &= 2^{p-2} Z_1^p \quad (z^p = 2^p Z_1^p) \quad \dots \textcircled{20}
\end{aligned}$$

$$\begin{cases} a = \frac{e}{b} & a = 2^{\frac{1}{2}}s & b = 2^{\frac{1}{2}}t \\ b = \frac{e}{a} \end{cases}$$

In this condition, the relationship of the following equation is maintained.

$$\begin{aligned}
ab &= e & a^2 + b^2 &= \frac{z^p}{2} \\
e &= 2^{m+1}d - 2^l c \\
X^p &= 2^p X_1^p = 2^2 2^m d \\
Z^p &= 2^p Z_1^p = 2^2 2^l c \\
2^{p-2} Y_1^p &= 2^l c - 2^m d
\end{aligned}$$

Proposition 13 $l \geq p-1$, $m \geq p-1$ $(c, d \in \text{odd number } l, m \in \mathbb{N})$

X_1^p , $Z_1^p \in \text{even number}$

$$2+l \geq p+1$$

$$2+m \geq p+1$$

$$Y_1^p \in \text{even number so } X_1^p , Z_1^p \in \text{even number.} \quad (7)$$

Proposition 14 $l = p-2$, $m \geq p-2$ $(c, d \in \text{odd number } l, m \in \mathbb{N})$

$e = 2^{p-2}(\text{odddnumber})$

$$\begin{aligned} e &= 2^{m+1}d - 2^l c \\ &= 2^{m+1}d - 2^{p-2}c \\ &= 2^{p-2} (2^{m+3-p}d - c) \end{aligned}$$

$$m+3 \geq p+1 \quad 2^{m+3-p}d \in \text{even number}$$

$$e = 2^{p-2}(\text{odd number})$$

$$e = 2^{p-2}w \quad (\text{put } w \in \text{odd number})$$

By referring to the ⑩.

$$\begin{aligned} e + \left(\frac{2}{3-2\sqrt{2}} - 2 \right) e &= 2^{p-2}Z_1^p \quad (e = 2^{p-2}w) \\ 2^{p-2}w + \left(\frac{2}{3-2\sqrt{2}} - 2 \right) 2^{p-2}w &= 2^{p-2}Z_1^p \\ w + \left(\frac{2}{3-2\sqrt{2}} - 2 \right) w &= Z_1^p \end{aligned}$$

$$w , Z_1^p \in \mathbb{N} \quad \left(\frac{2}{3-2\sqrt{2}} - 2 \right) w \neq \mathbb{N}$$

Therefore, $e = 2^{p-2}(\text{odddnumber})$ is not hold. (8)

$$X^p = 2^p X_1^p = 2^2 2^m d$$

$$Z^p = 2^p Z_1^p = 2^2 2^l c$$

$$2^{p-2}Y_1^p = 2^l c - 2^m d$$

$$l \geq p-1 \quad m = p-2$$

Condition $p < l < 2p-2$ is not hold. $(Z_1^p \in \text{even number})$

Proposition 15 $l \geq 2p-2$ $m = p-2$ $(c, d \in \text{odd number } l, m \in \mathbb{N})$

$$e = 2^{p-1} (\text{odddnumber})$$

$$l = 2p - 2 + k \quad (k = 0 \text{ or } \mathbb{N})$$

$$\begin{aligned} e &= 2^{m+1}d - 2^l c \\ &= 2^{p-1}d - 2^{2p-2+k}c \\ &= 2^{p-1} (d - 2^{p-1+k}c) \end{aligned}$$

$$\begin{aligned} h &= d - 2^{p-1+k}c \\ e &= 2^{p-1}h \quad (h \in \text{odd number}) \end{aligned}$$

By referring to the ⑩.

$$\begin{aligned} e + \left(\frac{2}{3-2\sqrt{2}} - 2 \right) e &= 2^{p-2} Z_1^p & (e = 2^{p-1}h) \\ 2^{p-1}h + \left(\frac{2}{3-2\sqrt{2}} - 2 \right) 2^{p-1}h &= 2^{p-2} Z_1^p \\ 2h + \left(\frac{2}{3-2\sqrt{2}} - 2 \right) 2h &= Z_1^p \end{aligned}$$

$$2h, Z_1^p \in \mathbb{N} \quad \left(\frac{2}{3-2\sqrt{2}} - 2 \right) 2h \notin \mathbb{N}$$

Therefore, $e = 2^{p-1} (\text{odddnumber})$ is not hold. (9)

3 As a result of the above.

$Y_1^p \in \text{even number}$ so $X_1^p, Z_1^p \in \text{even number}; (1), (6), (7)$
The contradictory to assumption; (2), (4), (5), (8), (9)

By referring to the (3),

$$\begin{aligned} U_{II}^p &= Z_{II}^p + X_{II}^p & V_{II}^p + X_{II}^p &= Z_{II}^p \\ (2U_{II})^p &= (2Z_{II})^p + (2X_{II})^p & (2V_{II})^p + (2X_{II})^p &= (2Z_{II})^p \\ (2Z_{II})^p &< Z^p = (2Z_I)^p & (2X_{II})^p &< X^p = (2X_I)^p \end{aligned}$$

Thus the lemma has been shown.

$$x^n + y^n \neq z^n \quad (xyz \neq 0 \quad n \geq 3)$$