

Integer Design of Solutions of One of the Diophantine Equations

$$\alpha(X^4 + Y^4)(P^2 + Q^2 + R^2 + S^2)$$

$$= (T^2 + U^2)(a^3 + b^3 + c^3)(C^2 - D^2)(Z^2 - W^2)P^\beta$$

with $X < Y < W < Z$ and P is ODD, $\alpha > 0, \beta > 0$

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ABSTRACT:

In this paper focused to study to find integer design of solutions Diophantine Equation $\alpha(X^4 + Y^4)(p^2 + q^2 + r^2 + s^2) = (t^2 + u^2)(a^3 + b^3 + c^3)(C^2 - D^2)(Z^2 - W^2)P^\beta$ with $\alpha > 0, \beta > 0$ with Mathematical induction method for $\beta = 1, 2, 3, 4, \dots$ and so on.

$$\text{Here } \{a, b, c\} = \left\{ \begin{array}{l} (-6, -8, 9), (9, 10, -12), (64, 94, -103), (-71, -138, 144), \\ (73, 144, -150), (-135, -138, 172), \\ (135, 235, -249) \\ (334, 438, -495), (-372, -426, 505), (-426, -486, 577), (-242, -720, 729) \end{array} \right\}$$

With $a^3 + b^3 + c^3 = 1$

In particularly, having integer design of solutions for $\beta > 2$ is

$$x = k^n, y = k^{n+1}, z = k^{n+3}, w = k^{n+2}, p = k^n, C = \left(\left(\frac{1+k^4}{2} \right)^2 + 1 \right) n,$$

$$D = \left(\left(\frac{1+k^4}{2} \right)^2 - 1 \right) n, \alpha = (1 + k^4)(k^6 - k^4)k^{(\beta-2)n}n^2, q = p + 1, r = \frac{p^2-1}{2},$$

$$s = \left(\frac{p+1}{2} \right)^2 - 1, t = \frac{p^2+1}{2}, u = \left(\frac{p+1}{2} \right)^2 + 1. \text{ whenever } 1 + k^4 \text{ is even, } p \text{ is odd}$$

and

$$x = k^n, y = k^{n+1}, z = k^{n+3}, w = k^{n+2}, p = k^n, C = \left(\frac{(1+k^4)^2+1}{2} \right) n, D = \left(\frac{(1+k^4)^2-1}{2} \right) n,$$

$$\alpha = (1 + k^4)(k^6 - k^4)k^{(\beta-2)n}n^2, q = p + 1, r = \frac{p^2-1}{2}, s = \left(\frac{p+1}{2} \right)^2 - 1, t = \frac{p^2+1}{2},$$

$$u = \left(\frac{p+1}{2} \right)^2 + 1. \text{ if } 1 + k^4 \text{ and } p \text{ is odd. Here } k \text{ must be positive integer.}$$

I. INTRODUCTION

Diophantine equations, which are polynomial equations restricted to integer solutions, occupy a central place in algebraic number theory. Within this broad framework, exponential and higher-degree forms—including quintic Diophantine equations—extend their significance beyond pure mathematics into applied scientific domains.

II. RESULTS & DISCUSSIONS:

Proportion 1: A Study on Diophantine Equation

$$\alpha(X^4 + Y^4)(p^2 + q^2 + r^2 + s^2) = (t^2 + u^2)(a^3 + b^3 + c^3)(C^2 - D^2)(Z^2 - W^2)P.$$

Clearly, we know that from Reference [1], $p^2 + q^2 + r^2 + s^2 = t^2 + u^2$ having different sets of integer solutions is illustrated below:

if p is odd then $q = p + 1$, $r = \frac{p^2-1}{2}$, $s = \left(\frac{p+1}{2}\right)^2 - 1$, $t = \frac{p^2+1}{2}$, $u = \left(\frac{p+1}{2}\right)^2 + 1$.

$$\text{Also, } \{a, b, c\} = \left\{ \begin{array}{l} (-6, -8, 9), (9, 10, -12), (64, 94, -103), (-71, -138, 144), \\ (73, 144, -150), (-135, -138, 172), \\ (135, 235, -249) \\ (334, 438, -495), (-372, -426, 505), (-426, -486, 577), (-242, -720, 729) \end{array} \right\}$$

With $a^3 + b^3 + c^3 = 1$

It follows that we go to prove that find integer design of solutions of

$$\alpha(X^4 + Y^4) = (C^2 - D^2)(Z^2 - W^2)P$$

Let $x = k^n$, $y = k^{n+1}$, $z = k^{n+3}$, $w = k^{n+2}$, $p = k^{2n}$, $q = p + 1$, $r = \frac{p^2-1}{2}$, $s = \left(\frac{p+1}{2}\right)^2 - 1$, $t = \frac{p^2+1}{2}$,

$u = \left(\frac{p+1}{2}\right)^2 + 1$.

Consider $\alpha(X^4 + Y^4) = \alpha k^{4n}(1 + k^4)$

Again consider $(Z^2 - W^2)P = k^{4n}(k^6 - k^4)$.

It follows that $\alpha(X^4 + Y^4) = (C^2 - D^2)(Z^2 - W^2)P$ implies that

$\alpha k^{4n}(1 + k^4) = (C^2 - D^2)k^{4n}(k^6 - k^4)$ implies $\alpha(1 + k^4) = (C^2 - D^2)(k^6 - k^4)$. Solve for α , whenever $(1 + k^4, D, C)$ becomes a Pythagorean Triplet.

From the References, we know that

if r is an even number, then $(r, \left(\frac{r}{2}\right)^2 - 1, \left(\frac{r}{2}\right)^2 + 1)$ is a Pythagorean triplet.

if r is an odd number, then $(r, \frac{r^2-1}{2}, \frac{r^2+1}{2})$ is a Pythagorean triplet.

It implies that $(1 + k^4, D, C)$ becomes a Pythagorean Triplet depends on $1 + k^4$ is it odd or even.

Case 1: If $1 + k^4$ is even, then $(1 + k^4, \left(\frac{1+k^4}{2}\right)^2 - 1, \left(\frac{1+k^4}{2}\right)^2 + 1)$ is a Pythagorean triplet. It follows that

$\alpha(1 + k^4) = (C^2 - D^2)(k^6 - k^4)$ and solve for α , whenever $(1 + k^4, D, C)$ becomes a Pythagorean Triplet with

$$C = \left(\left(\frac{1+k^4}{2}\right)^2 + 1\right)n, D = \left(\left(\frac{1+k^4}{2}\right)^2 - 1\right)n$$

$$C^2 - D^2 = (1 + k^4)^2 n^2 \text{ and hence } \alpha = (1 + k^4)(k^6 - k^4)n^2.$$

Hence, we obtain

$$\alpha(X^4 + Y^4)(p^2 + q^2 + r^2 + s^2) = (t^2 + u^2)(a^3 + b^3 + c^3)(C^2 - D^2)(Z^2 - W^2)P$$

having integer design of solution is

$$\text{Also, } \{a, b, c\} = \left\{ \begin{array}{l} (-6, -8, 9), (9, 10, -12), (64, 94, -103), (-71, -138, 144), \\ (73, 144, -150), (-135, -138, 172), \\ (135, 235, -249) \\ (334, 438, -495), (-372, -426, 505), (-426, -486, 577), (-242, -720, 729) \end{array} \right\}$$

With $a^3 + b^3 + c^3 = 1$, $x = k^n$, $y = k^{n+1}$, $z = k^{n+3}$, $w = k^{n+2}$, $p = k^{2n}$,

$$C = \left(\left(\frac{1+k^4}{2}\right)^2 + 1\right)n, D = \left(\left(\frac{1+k^4}{2}\right)^2 - 1\right)n, \alpha = (1 + k^4)(k^6 - k^4)n^2, q = p + 1,$$

$$r = \frac{p^2-1}{2}, s = \left(\frac{p+1}{2}\right)^2 - 1, t = \frac{p^2+1}{2}, u = \left(\frac{p+1}{2}\right)^2 + 1 \text{ when ever } p \text{ is odd.}$$

Case 2: If $1 + k^4$ is odd, then $(1 + k^4, \frac{(1+k^4)^2-1}{2}, \frac{(1+k^4)^2+1}{2})$ is a Pythagorean triplet. It follows that

$\alpha(1 + k^4) = (C^2 - D^2)(k^6 - k^4)$ and solve for α , whenever $(1 + k^4, D, C)$ becomes a Pythagorean Triplet with

$$C = \left(\frac{(1+k^4)^2+1}{2}\right)n, D = \left(\frac{(1+k^4)^2-1}{2}\right)n. \text{ Hence}$$

$$C^2 - D^2 = (1 + k^4)^2 n^2 \text{ and hence } \alpha = (1 + k^4)(k^6 - k^4)n^2.$$

Hence, we obtain $\alpha(X^4 + Y^4) = (C^2 - D^2)(Z^2 - W^2)P$.

Having an integer design of solution is $x = k^n$, $y = k^{n+1}$, $z = k^{n+3}$, $w = k^{n+2}$, $p = k^{2n}$,

$$C = \left(\frac{(1+k^4)^2+1}{2}\right)n, D = \left(\frac{(1+k^4)^2-1}{2}\right)n, \alpha = (1 + k^4)(k^6 - k^4).$$

E.g. 1: Suppose $k = 2$ then $1 + k^4 = 17$, is odd; Having an integer design of solution is

$$x = 2^n, y = 2^{n+1}, z = 2^{n+3}, w = 2^{n+2}, p = 2^{2n},$$

$$C = \left(\frac{(1+2^4)^2 + 1}{2} \right) n = 145n, D = \left(\frac{(1+2^4)^2 - 1}{2} \right) = 144n$$

$$C^2 - D^2 = (1 + 2^4)^2 n^2, \alpha = (1 + 2^4)(2^6 - 2^4)n^2.$$

Suppose $n = 1$; then $x = 2, y = 4, z = 16, w = 8, p = 4$,

$$C = \left(\frac{(1+2^4)^2 + 1}{2} \right) = 145, D = \left(\frac{(1+2^4)^2 - 1}{2} \right) = 144$$

$$C^2 - D^2 = (1 + 2^4)^2 = 289, \alpha = (1 + 2^4)(2^6 - 2^4) = 816.$$

$$\text{Consider LHS} = \alpha(X^4 + Y^4) = 816(2^4 + 4^4) = 221952.$$

$$\text{RHS} = (C^2 - D^2)(Z^2 - W^2)P = 289 * (16^2 - 8^2) * 4 = 221952.$$

E.g. 2: Suppose $k = 3$ then $1 + k^4 = 82$, is even; Having an integer design of solution is

$$x = 3^n, y = 3^{n+1}, z = 3^{n+3}, w = 3^{n+2}, p = 3^{2n},$$

$$C = \left(\left(\frac{1+3^4}{2} \right)^2 + 1 \right) n = 1681n, D = \left(\left(\frac{1+3^4}{2} \right)^2 - 1 \right) n = 1600n$$

$$C^2 - D^2 = (1 + 3^4)^2 n^2 = 6724n^2, \alpha = (1 + 3^4)(3^6 - 3^4)n^2 = 53136n^2.$$

$$\text{Suppose } n = 1; \text{ then } x = 3, y = 9, z = 81, w = 27, p = 9, C^2 - D^2 = 6724, \alpha = 53136$$

$$\text{Consider LHS} = \alpha(X^4 + Y^4) = 53136(3^4 + 9^4) = 352929312.$$

$$\text{RHS} = (C^2 - D^2)(Z^2 - W^2)P = 6724 * (81^2 - 27^2) * 9 = 352929312.$$

Proportion 2: A Study on Diophantine Equation

$$\alpha(X^4 + Y^4)(p^2 + q^2 + r^2 + s^2) = (t^2 + u^2)(a^3 + b^3 + c^3)(C^2 - D^2)(Z^2 - W^2)P^2$$

Clearly, we know that from Reference [1], $p^2 + q^2 + r^2 + s^2 = t^2 + u^2$ having different sets of integer solutions is illustrated below:

$$\text{if } p \text{ is odd then } q = p + 1, r = \frac{p^2-1}{2}, s = \left(\frac{p+1}{2} \right)^2 - 1, t = \frac{p^2+1}{2}, u = \left(\frac{p+1}{2} \right)^2 + 1.$$

$$\text{Also, } \{a, b, c\} = \left\{ \begin{array}{l} (-6, -8, 9), (9, 10, -12), (64, 94, -103), (-71, -138, 144), \\ (73, 144, -150), (-135, -138, 172), \\ (135, 235, -249) \\ (334, 438, -495), (-372, -426, 505), (-426, -486, 577), (-242, -720, 729) \end{array} \right\}$$

$$\text{With } a^3 + b^3 + c^3 = 1$$

$$\text{Now we can find integer design of solutions of } \alpha(X^4 + Y^4) = (C^2 - D^2)(Z^2 - W^2)P^2$$

$$\text{Let } x = k^n, y = k^{n+1}, z = k^{n+3}, w = k^{n+2}, p = k^n$$

$$\text{Consider } \alpha(X^4 + Y^4) = \alpha k^{4n}(1 + k^4)$$

$$\text{Again consider } (Z^2 - W^2)P^2 = k^{4n}(k^6 - k^4).$$

$$\text{It follows that } \alpha(X^4 + Y^4) = (C^2 - D^2)(Z^2 - W^2)P^2 \text{ implies that}$$

$$\alpha k^{4n}(1 + k^4) = (C^2 - D^2)k^{4n}(k^6 - k^4) \text{ implies } \alpha(1 + k^4) = (C^2 - D^2)(k^6 - k^4). \text{ Solve for } \alpha, \text{ whenever } (1 + k^4, D, C) \text{ becomes a Pythagorean Triplet.}$$

From the References, we know that

$$\text{if } r \text{ is an even number, then } \left(r, \left(\frac{r}{2} \right)^2 - 1, \left(\frac{r}{2} \right)^2 + 1 \right) \text{ is a Pythagorean triplet.}$$

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It implies that $(1 + k^4, D, C)$ becomes a Pythagorean Triplet depends on $1 + k^4$ is it odd or even.

Case 1: If $1 + k^4$ is even, then $\left(1 + k^4, \left(\frac{1+k^4}{2} \right)^2 - 1, \left(\frac{1+k^4}{2} \right)^2 + 1 \right)$ is a Pythagorean triplet. It follows that

$$\alpha(1 + k^4) = (C^2 - D^2)(k^6 - k^4) \text{ and solve for } \alpha, \text{ whenever } (1 + k^4, D, C) \text{ becomes a Pythagorean Triplet with}$$

$$C = \left(\left(\frac{1+k^4}{2} \right)^2 + 1 \right) n, D = \left(\left(\frac{1+k^4}{2} \right)^2 - 1 \right) n$$

$$C^2 - D^2 = (1 + k^4)^2 n^2 \text{ and hence } \alpha = (1 + k^4)(k^6 - k^4)n^2.$$

Hence, we obtain

$$\alpha(X^4 + Y^4)(p^2 + q^2 + r^2 + s^2) = (t^2 + u^2)(a^3 + b^3 + c^3)(C^2 - D^2)(Z^2 - W^2)P^2$$

$$\text{having integer design of solution is } x = k^n, y = k^{n+1}, z = k^{n+3}, w = k^{n+2}, p = k^n, C = \left(\left(\frac{1+k^4}{2} \right)^2 + 1 \right) n, D =$$

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With $a^3 + b^3 + c^3 = 1$

Case 2: If $1 + k^4$ is odd, then $(1 + k^4, \frac{(1+k^4)^2-1}{2}, \frac{(1+k^4)^2+1}{2})$ is a Pythagorean triplet. It follows that $\alpha(1 + k^4) = (C^2 - D^2)(k^6 - k^4)$ and solve for α , whenever $(1 + k^4, D, C)$ becomes a Pythagorean Triplet with $C = \left(\frac{(1+k^4)^2+1}{2}\right)n, D = \left(\frac{(1+k^4)^2-1}{2}\right)n$.

Hence $C^2 - D^2 = (1 + k^4)^2 n^2$ and hence $\alpha = (1 + k^4)(k^6 - k^4)n^2$.

Hence, we obtain

$\alpha(X^4 + Y^4)(p^2 + q^2 + r^2 + s^2) = (t^2 + u^2)(a^3 + b^3 + c^3)(C^2 - D^2)(Z^2 - W^2)P^2$, having an integer design of solution is $x = k^n, y = k^{n+1}, z = k^{n+3}, w = k^{n+2}, p = k^n$,

$$C = \left(\frac{(1+k^4)^2+1}{2}\right)n, D = \left(\frac{(1+k^4)^2-1}{2}\right)n, \alpha = (1 + k^4)(k^6 - k^4)n^2.$$

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$$x = 2^n, y = 2^{n+1}, z = 2^{n+3}, w = 2^{n+2}, p = 2^n,$$

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Suppose $n = 1$;

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$$x = 3^n, y = 3^{n+1}, z = 3^{n+3}, w = 3^{n+2}, p = 3^{2n}, C = \left(\left(\frac{1+3^4}{2}\right)^2 + 1\right)n = 1681n,$$

$$D = \left(\left(\frac{1+3^4}{2}\right)^2 - 1\right)n = 1600n, C^2 - D^2 = (1 + 3^4)^2 n^2 = 6724n,$$

$$\alpha = (1 + 3^4)(3^6 - 3^4)n^2 = 53136n^2.$$

Suppose $n = 1$;

$$\text{then } x = 3, y = 9, z = 81, w = 27, p = 3, C = \left(\left(\frac{1+3^4}{2}\right)^2 + 1\right) = 1681,$$

$$D = \left(\left(\frac{1+3^4}{2}\right)^2 - 1\right) = 1600, C^2 - D^2 = 6724, \alpha = 53136$$

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With $a^3 + b^3 + c^3 = 1$

Now we can find integer design of solutions of $\alpha(X^4 + Y^4) = (C^2 - D^2)(Z^2 - W^2)P^3$

Let $x = k^n, y = k^{n+1}, z = k^{n+3}, w = k^{n+2}, p = k^n$

Consider $\alpha(X^4 + Y^4) = \alpha k^{4n}(1 + k^4)$

Again consider $(Z^2 - W^2)P^3 = k^{5n}(k^6 - k^4)$.

It follows that $\alpha(X^4 + Y^4) = (C^2 - D^2)(Z^2 - W^2)P^3$ implies that

$\alpha k^{4n}(1 + k^4) = (C^2 - D^2)k^{5n}(k^6 - k^4)$ implies $\alpha(1 + k^4) = (C^2 - D^2)(k^6 - k^4)k^n$. Solve for α , whenever $(1 + k^4, D, C)$ becomes a Pythagorean Triplet.

From the References, It implies that $(1 + k^4, D, C)$ becomes a Pythagorean Triplet depends on $1 + k^4$ is it odd or even.

Case 1: If $1 + k^4$ is even, then $(1 + k^4, \left(\frac{1+k^4}{2}\right)^2 - 1, \left(\frac{1+k^4}{2}\right)^2 + 1)$ is a Pythagorean triplet. It follows that $\alpha(1 + k^4) = (C^2 - D^2)(k^6 - k^4)k^n$ and solve for α , whenever $(1 + k^4, D, C)$ becomes a Pythagorean Triplet

with $C = \left(\left(\frac{1+k^4}{2}\right)^2 + 1\right)n, D = \left(\left(\frac{1+k^4}{2}\right)^2 - 1\right)n$

$C^2 - D^2 = (1 + k^4)^2 n^2$ and hence $\alpha = (1 + k^4)(k^6 - k^4)k^n n^2$.

Hence, we obtain

$\alpha(X^4 + Y^4)(p^2 + q^2 + r^2 + s^2) = (t^2 + u^2)(a^3 + b^3 + c^3)(C^2 - D^2)(Z^2 - W^2)P^3$

having integer design of solution is $x = k^n, y = k^{n+1}, z = k^{n+3}, w = k^{n+2}, p = k^n, C = \left(\left(\frac{1+k^4}{2}\right)^2 + 1\right)n,$

$D = \left(\left(\frac{1+k^4}{2}\right)^2 - 1\right)n, \alpha = (1 + k^4)(k^6 - k^4)k^n n^2.$

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With $a^3 + b^3 + c^3 = 1$

Case 2: If $1 + k^4$ is odd, then $(1 + k^4, \frac{(1+k^4)^2 - 1}{2}, \frac{(1+k^4)^2 + 1}{2})$ is a Pythagorean triplet. It follows that $\alpha(1 + k^4) = (C^2 - D^2)(k^6 - k^4)k^n$ and solve for α , whenever $(1 + k^4, D, C)$ becomes a Pythagorean Triplet with $C = \left(\frac{(1+k^4)^2 + 1}{2}\right)n, D = \left(\frac{(1+k^4)^2 - 1}{2}\right)n$. Hence

$C^2 - D^2 = (1 + k^4)^2 n^2$ and hence $\alpha = (1 + k^4)(k^6 - k^4)k^n n^2$.

Hence, we obtain

$\alpha(X^4 + Y^4)(p^2 + q^2 + r^2 + s^2) = (t^2 + u^2)(a^3 + b^3 + c^3)(C^2 - D^2)(Z^2 - W^2)P^3$ having an integer design of solution is $x = k^n, y = k^{n+1}, z = k^{n+3}, w = k^{n+2}, p = k^n,$

$C = \left(\frac{(1+k^4)^2 + 1}{2}\right)n, D = \left(\frac{(1+k^4)^2 - 1}{2}\right)n, \alpha = (1 + k^4)(k^6 - k^4)k^n n^2.$

$$\text{Also, } \{a, b, c\} = \left\{ \begin{array}{l} (-6, -8, 9), (9, 10, -12), (64, 94, -103), (-71, -138, 144), \\ (73, 144, -150), (-135, -138, 172), \\ (135, 235, -249) \\ (334, 438, -495), (-372, -426, 505), (-426, -486, 577), (-242, -720, 729) \end{array} \right\}$$

With $a^3 + b^3 + c^3 = 1$

E.g. 1: Suppose $k = 2$ then $1 + k^4 = 17$, is odd; Having an integer design of solution is

$x = 2^n, y = 2^{n+1}, z = 2^{n+3}, w = 2^{n+2}, p = 2^n,$

$C = \left(\frac{(1+2^4)^2 + 1}{2}\right)n = 145n, D = \left(\frac{(1+2^4)^2 - 1}{2}\right)n = 144nn$

$C^2 - D^2 = (1 + 2^4)^2 n^2, \alpha = (1 + 2^4)(2^6 - 2^4) * 2^n * n^2.$

Suppose $n = 1$;

then $x = 2, y = 4, z = 16, w = 8, p = 2, C = \left(\frac{(1+2^4)^2+1}{2}\right) = 145, D = \left(\frac{(1+2^4)^2-1}{2}\right) = 144$

$$C^2 - D^2 = (1 + 2^4)^2 = 289, \alpha = (1 + 2^4)(2^6 - 2^4) * 2 = 1632.$$

Consider **LHS** = $\alpha(X^4 + Y^4) = 1632 * (2^4 + 4^4) = 443904$.

$$\text{RHS} = (C^2 - D^2)(Z^2 - W^2)P^3 = 289 * (16^2 - 8^2) * 8 = 443904.$$

E.g. 2: Suppose $k = 3$ then $1 + k^4 = 82$, is even; Having an integer design of solution is

$$x = 3^n, y = 3^{n+1}, z = 3^{n+3}, w = 3^{n+2}, p = 3^n, C = \left(\left(\frac{1+3^4}{2}\right)^2 + 1\right)n = 1681n,$$

$$D = \left(\left(\frac{1+3^4}{2}\right)^2 - 1\right)n = 1600n, C^2 - D^2 = (1 + 3^4)^2 n^2 = 6724n,$$

$$\alpha = (1 + 3^4)(3^6 - 3^4)3^n n^2 = 53136 * 3^n * n^2.$$

Suppose $n = 1$;

$$\text{then } x = 3, y = 9, z = 81, w = 27, p = 3, C = \left(\left(\frac{1+3^4}{2}\right)^2 + 1\right) = 1681,$$

$$D = \left(\left(\frac{1+3^4}{2}\right)^2 - 1\right) = 1600, C^2 - D^2 = 6724, \alpha = 159408$$

Consider **LHS** = $\alpha(X^4 + Y^4) = 159408(3^4 + 9^4) = 1058787936$.

$$\text{RHS} = (C^2 - D^2)(Z^2 - W^2)P^3 = 6724 * (81^2 - 27^2) * 27 = 1058787936.$$

Proportion 4: A Study on Diophantine Equation

$$\alpha(X^4 + Y^4)(p^2 + q^2 + r^2 + s^2) = (t^2 + u^2)(a^3 + b^3 + c^3)(C^2 - D^2)(Z^2 - W^2)P^4$$

Clearly, we know that from Reference [1], $p^2 + q^2 + r^2 + s^2 = t^2 + u^2$ having different sets of integer solutions is illustrated below:

if p is odd then $q = p + 1, r = \frac{p^2-1}{2}, s = \left(\frac{p+1}{2}\right)^2 - 1, t = \frac{p^2+1}{2}, u = \left(\frac{p+1}{2}\right)^2 + 1$.

$$\text{Also, } \{a, b, c\} = \left\{ \begin{array}{l} (-6, -8, 9), (9, 10, -12), (64, 94, -103), (-71, -138, 144), \\ (73, 144, -150), (-135, -138, 172), \\ (135, 235, -249) \\ (334, 438, -495), (-372, -426, 505), (-426, -486, 577), (-242, -720, 729) \end{array} \right\}$$

With $a^3 + b^3 + c^3 = 1$

Now we can find integer design of solutions of $\alpha(X^4 + Y^4) = (C^2 - D^2)(Z^2 - W^2)P^4$

Let $x = k^n, y = k^{n+1}, z = k^{n+3}, w = k^{n+2}, p = k^n$

Consider $\alpha(X^4 + Y^4) = \alpha k^{4n}(1 + k^4)$. Again consider $(Z^2 - W^2)P^4 = k^{6n}(k^6 - k^4)$.

It follows that $\alpha(X^4 + Y^4)(p^2 + q^2 + r^2 + s^2) = (t^2 + u^2)(C^2 - D^2)(Z^2 - W^2)P^4$

implies that $\alpha k^{4n}(1 + k^4) = (C^2 - D^2)k^{6n}(k^6 - k^4)$ implies

$\alpha(1 + k^4) = (C^2 - D^2)(k^6 - k^4)k^{2n}$. Solve for α , whenever $(1 + k^4, D, C)$ becomes a Pythagorean Triplet.

From the References, we know that

It implies that $(1 + k^4, D, C)$ becomes a Pythagorean Triplet depends on $1 + k^4$ is it odd or even.

Case 1: If $1 + k^4$ is even, then $(1 + k^4, \left(\frac{1+k^4}{2}\right)^2 - 1, \left(\frac{1+k^4}{2}\right)^2 + 1)$ is a Pythagorean triplet. It follows that

$\alpha(1 + k^4) = (C^2 - D^2)(k^6 - k^4)k^n$ and solve for α , whenever $(1 + k^4, D, C)$ becomes a Pythagorean Triplet

$$\text{with } C = \left(\left(\frac{1+k^4}{2}\right)^2 + 1\right)n, D = \left(\left(\frac{1+k^4}{2}\right)^2 - 1\right)n$$

$$C^2 - D^2 = (1 + k^4)^2 n^2 \text{ and hence } \alpha = (1 + k^4)(k^6 - k^4)k^{2n}n^2.$$

$$\text{Also, } \{a, b, c\} = \left\{ \begin{array}{l} (-6, -8, 9), (9, 10, -12), (64, 94, -103), (-71, -138, 144), \\ (73, 144, -150), (-135, -138, 172), \\ (135, 235, -249) \\ (334, 438, -495), (-372, -426, 505), (-426, -486, 577), (-242, -720, 729) \end{array} \right\}$$

With $a^3 + b^3 + c^3 = 1$

Hence, we obtain

$$\alpha(X^4 + Y^4)(p^2 + q^2 + r^2 + s^2) = (t^2 + u^2)(a^3 + b^3 + c^3)(C^2 - D^2)(Z^2 - W^2)P^4$$

having integer design of solution is $x = k^n, y = k^{n+1}, z = k^{n+3}, w = k^{n+2}, p = k^n, C = \left(\left(\frac{1+k^4}{2}\right)^2 + 1\right)n, D = \left(\left(\frac{1+k^4}{2}\right)^2 - 1\right)n, \alpha = (1+k^4)(k^6 - k^4)k^{2n}n^2$.

Case 2: If $1 + k^4$ is odd, then $(1 + k^4, \frac{(1+k^4)^2-1}{2}, \frac{(1+k^4)^2+1}{2})$ is a Pythagorean triplet. It follows that $\alpha(1 + k^4) = (C^2 - D^2)(k^6 - k^4)k^n$ and solve for α , whenever $(1 + k^4, D, C)$ becomes a Pythagorean Triplet with $C = \left(\frac{(1+k^4)^2+1}{2}\right)n, D = \left(\frac{(1+k^4)^2-1}{2}\right)n$. Hence $C^2 - D^2 = (1 + k^4)^2n^2$ and hence $\alpha = (1 + k^4)(k^6 - k^4)k^{2n}n^2$.

Hence, we obtain

$\alpha(X^4 + Y^4)(p^2 + q^2 + r^2 + s^2) = (t^2 + u^2)(a^3 + b^3 + c^3)(C^2 - D^2)(Z^2 - W^2)P^4$,
having an integer design of solution is $x = k^n, y = k^{n+1}, z = k^{n+3}, w = k^{n+2}, p = k^n$,

$C = \left(\frac{(1+k^4)^2+1}{2}\right)n, D = \left(\frac{(1+k^4)^2-1}{2}\right)n, \alpha = (1 + k^4)(k^6 - k^4)k^{2n}n^2$.

Also, $\{a, b, c\} = \left\{ \begin{array}{l} (-6, -8, 9), (9, 10, -12), (64, 94, -103), (-71, -138, 144), \\ (73, 144, -150), (-135, -138, 172), \\ (135, 235, -249) \\ (334, 438, -495), (-372, -426, 505), (-426, -486, 577), (-242, -720, 729) \end{array} \right\}$

With $a^3 + b^3 + c^3 = 1$

E.g. 1: Suppose $k = 2$ then $1 + k^4 = 17$, is odd; Having an integer design of solution is $x = 2^n, y = 2^{n+1}, z = 2^{n+3}, w = 2^{n+2}, p = 2^n$,

$C = \left(\frac{(1+2^4)^2+1}{2}\right)n = 145n, D = \left(\frac{(1+2^4)^2-1}{2}\right)n = 144n; C^2 - D^2 = (1 + 2^4)^2n^2$,
 $\alpha = (1 + 2^4)(2^6 - 2^4) * 2^{2n} * n^2$.

Suppose $n = 1$;

then $x = 2, y = 4, z = 16, w = 8, p = 2, C = \left(\frac{(1+2^4)^2+1}{2}\right) = 145, D = \left(\frac{(1+2^4)^2-1}{2}\right) = 144$

$C^2 - D^2 = (1 + 2^4)^2 = 289, \alpha = (1 + 2^4)(2^6 - 2^4) * 4 = 3264$.

Consider **LHS** = $\alpha(X^4 + Y^4) = 3264 * (2^4 + 4^4) = 887808$.

RHS = $(C^2 - D^2)(Z^2 - W^2)P^4 = 289 * (16^2 - 8^2) * 16 = 887808$.

E.g. 2: Suppose $k = 3$ then $1 + k^4 = 82$, is even; Having an integer design of solution is

$x = 3^n, y = 3^{n+1}, z = 3^{n+3}, w = 3^{n+2}, p = 3^n, C = \left(\left(\frac{1+3^4}{2}\right)^2 + 1\right)n = 1681n$,

$D = \left(\left(\frac{1+3^4}{2}\right)^2 - 1\right)n = 1600n, C^2 - D^2 = (1 + 3^4)^2n^2 = 6724n$,

$\alpha = (1 + 3^4)(3^6 - 3^4)3^{2n}n^2 = 53136 * 3^{2n} * n^2$.

Suppose $n = 1$; then $x = 3, y = 9, z = 81, w = 27, p = 3, C = \left(\left(\frac{1+3^4}{2}\right)^2 + 1\right) = 1681$,

$D = \left(\left(\frac{1+3^4}{2}\right)^2 - 1\right) = 1600, C^2 - D^2 = 6724, \alpha = 478224$

Consider **LHS** = $\alpha(X^4 + Y^4) = 478224 * (3^4 + 9^4) = 3176363808$.

RHS = $(C^2 - D^2)(Z^2 - W^2)P^4 = 6724 * (81^2 - 27^2) * 81 = 3176363808$.

Main result:

A STUDY ON

$\alpha(X^4 + Y^4)(p^2 + q^2 + r^2 + s^2) = (t^2 + u^2)(a^3 + b^3 + c^3)(C^2 - D^2)(Z^2 - W^2)P^\beta$ with $\alpha > 0, \beta > 0$.

Clearly, we know that from Reference [1], $p^2 + q^2 + r^2 + s^2 = t^2 + u^2$ having different sets of integer solutions is illustrated below:

if p is odd then $q = p + 1, r = \frac{p^2-1}{2}, s = \left(\frac{p+1}{2}\right)^2 - 1, t = \frac{p^2+1}{2}, u = \left(\frac{p+1}{2}\right)^2 + 1$.

$$\text{Also, } \{a, b, c\} = \left\{ \begin{array}{l} (-6, -8, 9), (9, 10, -12), (64, 94, -103), (-71, -138, 144), \\ (73, 144, -150), (-135, -138, 172), \\ (135, 235, -249) \\ (334, 438, -495), (-372, -426, 505), (-426, -486, 577), (-242, -720, 729) \end{array} \right\}$$

With $a^3 + b^3 + c^3 = 1$

Now we can find integer design of solutions of

$$\alpha(X^4 + Y^4) = (C^2 - D^2)(a^3 + b^3 + c^3)(Z^2 - W^2)P^\beta$$

Having integer design of solutions for $\beta > 2$ is

$$x = k^n, y = k^{n+1}, z = k^{n+3}, w = k^{n+2}, p = k^n, C = \left(\left(\frac{1+k^4}{2} \right)^2 + 1 \right) n,$$

$$D = \left(\left(\frac{1+k^4}{2} \right)^2 - 1 \right) n, \alpha = (1 + k^4)(k^6 - k^4)k^{(\beta-2)n}n^2, \text{ If } 1 + k^4 \text{ is even and}$$

$$x = k^n, y = k^{n+1}, z = k^{n+3}, w = k^{n+2}, p = k^n,$$

$$C = \left(\frac{(1+k^4)^2 + 1}{2} \right) n, D = \left(\frac{(1+k^4)^2 - 1}{2} \right) n, \alpha = (1 + k^4)(k^6 - k^4)k^{(\beta-2)n}n^2 \text{ if } 1 + k^4 \text{ is odd.}$$

CONCLUSION

This equation generalizes classical Diophantine problems, blending sums of fourth powers with multiplicative factorizations. While challenging, targeted parametrization and modular analysis can yield solutions. Future work may classify solutions for specific α, β or link to broader number-theoretic frameworks. The parametric framework provides infinite families of solutions by exploiting algebraic identities and modular arithmetic. Future work could explore non-parametric solutions or generalizations to higher exponents.

Integer design of solutions Diophantine Equation

$$\alpha(X^4 + Y^4)(p^2 + q^2 + r^2 + s^2) = (t^2 + u^2)(a^3 + b^3 + c^3)(C^2 - D^2)(Z^2 - W^2)P^\beta \quad \text{with}$$

$\alpha > 0, \beta > 0$ with Mathematical induction method for $\beta = 1, 2, 3, 4, \dots$ and so on.

$$\text{Also, } \{a, b, c\} = \left\{ \begin{array}{l} (-6, -8, 9), (9, 10, -12), (64, 94, -103), (-71, -138, 144), \\ (73, 144, -150), (-135, -138, 172), \\ (135, 235, -249) \\ (334, 438, -495), (-372, -426, 505), (-426, -486, 577), (-242, -720, 729) \end{array} \right\}$$

With $a^3 + b^3 + c^3 = 1$

Having integer design of solutions for $\beta > 2$ is

$$x = k^n, y = k^{n+1}, z = k^{n+3}, w = k^{n+2}, p = k^n, C = \left(\left(\frac{1+k^4}{2} \right)^2 + 1 \right) n,$$

$$D = \left(\left(\frac{1+k^4}{2} \right)^2 - 1 \right) n, \alpha = (1 + k^4)(k^6 - k^4)k^{(\beta-2)n}n^2, q = p + 1, r = \frac{p^2-1}{2},$$

$$s = \left(\frac{p+1}{2} \right)^2 - 1, t = \frac{p^2+1}{2}, u = \left(\frac{p+1}{2} \right)^2 + 1. \text{ whenever } 1 + k^4 \text{ is even, } p \text{ is odd}$$

and

$$x = k^n, y = k^{n+1}, z = k^{n+3}, w = k^{n+2}, p = k^n, C = \left(\frac{(1+k^4)^2 + 1}{2} \right) n, D = \left(\frac{(1+k^4)^2 - 1}{2} \right) n,$$

$$\alpha = (1 + k^4)(k^6 - k^4)k^{(\beta-2)n}n^2, q = p + 1, r = \frac{p^2-1}{2}, s = \left(\frac{p+1}{2} \right)^2 - 1, t = \frac{p^2+1}{2},$$

$$u = \left(\frac{p+1}{2} \right)^2 + 1. \text{ if } 1 + k^4 \text{ and } p \text{ is odd. Here } k \text{ must be positive integer}$$

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