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费马大定理的初等证明方法

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摘要: 给出不定方程 $X^n + Y^n = Z^n$ 在 n 为奇素数时, 无正整数解的初等证明方法, 即用初等数学方法证明了费马大定理. 通过实例分析, 结果显示文中证明方法的正确.
关键词: 费马大定理; 初等数学方法; 因式分解; 多项式互素
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Elementary Proof of Fermat Theorem

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Abstract: In this paper, an elementary proof method is given for the indefinite equation, $X^n + Y^n = Z^n$, which has no positive integer solution when n is an odd prime number, namely, it proves Fermat theorem with an elementary mathematical method. In addition, an example analysis is also given, and the results show that the proof method is correct.
Keywords: Fermat theorem; elementary mathematical method; factorization; relatively prime of polynomials

1 预备知识

费马大定理也称“费马猜想”, 是十七世纪法国数学家费马提出的, 他认为: 一整数 3 次幂不能表为两个整数的同次幂之和; 一个整数 4 次幂不能表为两个整数的同次幂之和; 一般地讲, 当 $n > 2$, 一个整数的 n 次幂表为两个整数的同次幂之和, 这是不可能的. 即对于 $X^n + Y^n = Z^n$, 当 $n > 2$ 时, 不定方程无全正整数解.

“费马猜想”包含两层意义: 1) 当 p (p 为任意奇素数) 时, X, Y, Z 中一定有一个不为整数; 2) 当 $n = 4p$ 时, 出现两个方程, $(X^p)^4 + (Y^p)^4 = (Z^p)^4$, $(X^4)^p + (Y^4)^p = (Z^4)^p$, 若 X, Y 为正整数, 必须首先是 Z^p, Z^4 不为整数, 而后得 Z 不为整数. 因此, 只要证明当 $n = 4, n = p$ 时, Z 不为整数即可. 以前有种观点, 只要证明 $n = 4$ 的“费马猜想”成立, 随之 $n = 4p$ 的“费马猜想”也成立, 这是概念上的错误^[1].

“费马猜想”被提出后,经无数人辨证,先后证得 $n=3, n=4, n=5, n=7$, 以及一些有限数时费马大定理成立. 最终,在 1995 年被英国数学家安德鲁·怀尔斯所证明. 但怀尔斯的证明高深冗长. 费马在提出猜想的同时又说,他有一个绝妙的证明方法,只是“边页太小,写不下了”. 他的证明到底是个怎样的证明,至今仍是一个谜. 但可以肯定,费马处于当时的数学发展水平,他的证明肯定不是类似怀尔斯的证明,而是一个较为初等的方法^[2].

在怀尔斯的证明之后,世界上仍有不少数学志士为此而着迷,极具代表性的是美国数学家科林·迈克拉蒂. 2003 年,他称有比怀尔斯的更简单的方法,并先后在美国和加拿大的数学报告会上发表,取得极大的进展. 但他使用近代的“群论”思想,这与费马所称的方法仍是相去甚远^[3].

2 费马定理的证明

2.1 对 Z 进行因式分解

令 n 为任意奇素数 k , 当 $k \geq 3$ 时,有

$$Z^k = X^k + Y^k. \tag{1}$$

设式(1)有一组正整数解 X_0, Y_0, Z_0 , 且 Z_0 是最小的正整数解, 则式(1)变换为

$$Z_0^k = X_0^k + Y_0^k. \tag{2}$$

式(2)中:若 $(X_0, Y_0) = U_1$, 则 $U_1 | Z_0$. 于是有 $X'_0 = X_0/U_1, Y'_0 = Y_0/U_1, Z'_0 = Z_0/U_1$, 则式(2)变为

$$Z'^k_0 = X'^k_0 + Y'^k_0 = (Z_0/U_1)^k.$$

2.2 Z_0 的求解

Z 因式分解后,求解 Z_0 , 由于有

$$\left. \begin{aligned} Z_{01}^k &= U(x, y) = X_0 + Y_0, \\ Z_{02}^k &= V(x, y) = X_0^{(k-1)} + Y_0^{(k-2)}Y_0 + \cdots - X_0Y_0^{(k-2)} + Y_0^{(k-1)}. \end{aligned} \right\} \tag{3}$$

将 $X_0 = Z_{01}^k - Y_0$ 代入式(2), 可得

$$\begin{aligned} Z_0^k &= (Z_{01}^k - Y_0)^k + Y_0^k = \\ &= (Z_{01}^k)^k - C_k^1 (Z_{01}^k)^{(k-1)} Y_0 + C_k^2 (Z_{01}^k)^{(k-2)} Y_0^2 - \cdots + C_k^{(k-1)} (Z_{01}^k) Y_0^{(k-1)} - Y_0^k + Y_0^k. \end{aligned}$$

上式右端共 $(k+1)+1=k+2$ 项, 经移项并消项可得

$$(Z_{01}^k)^k - Z_0^k = C_k^1 (Z_{01}^k)^{(k-1)} Y_0 - C_k^2 (Z_{01}^k)^{(k-2)} Y_0^2 + \cdots + C_k^{k-2} (Z_{01}^k) Y_0^{(k-2)} - C_k^{k-1} (Z_{01}^k) Y_0^{(k-1)}.$$

上式右端 $k-1$ 项, 正负相间, Y_0 的系数都为组合数, 每一组合数皆含有 k 因子^[1], 且有 $C_k^1 = C_k^{k-1} = k, C_k^2 = C_k^{k-2}, \cdots$, 每一项皆有 k, Z_{01}^k, Y_0 因子. 所以, 上式可变换为

$$(Z_{01}^k)^k - Z_0^k = Z_{01}^k k Y_0 \left[(Z_{01}^k)^{(k-2)} - \left(\frac{C_k^2}{k}\right) (Z_{01}^k)^{(k-3)} Y_0 + \cdots + \left(\frac{C_k^{k-2}}{k}\right) (Z_{01}^k) Y_0^{(k-3)} - Y_0^{(k-2)} \right]. \tag{4}$$

设上式右端中括号内代数之和为 $\sum M'_1$, 且将 $Z_{01}^k = X_0 + Y_0$ 代入 $\sum M'_1$, 用二项式定理展开得

1) 第 1 项为

$$(X_0 + Y_0)^{(k-2)} = X_0^{(k-2)} + C_{k-2}^2 X_0^{(k-3)} Y_0 + \cdots + C_{k-2}^{(k-3)} X_0 Y_0^{(k-3)} + Y_0^{(k-2)};$$

2) 第 2 项为

$$-\left(\frac{C_k^2}{k}\right) (X_0 + Y_0)^{k-3} Y_0 = -\left(\frac{C_k^2}{k}\right) [X_0^{(k-3)} Y_0 + C_{k-3}^1 X_0^{(k-4)} Y_0^2 + \cdots + 1 C_{k-3}^{(k-4)} X_0 Y_0^{(k-3)}] - \left(\frac{C_k^2}{k}\right) Y_0^{(k-2)};$$

3) 第 $k-2$ 项为

$$\left(\frac{C_k^{k-2}}{k}\right) (X_0 + Y_0) Y_0^{k-3} = \left(\frac{C_k^{k-2}}{k}\right) X_0 Y_0^{(k-3)} + \left(\frac{C_k^{k-2}}{k}\right) Y_0^{(k-2)};$$

4) 第 $k-1$ 项为

$$-Y_0^{(k-2)} = -Y_0^{(k-2)}.$$

2.3 引理及其证明

引理 1 自然数集合中任意相邻两数 a 和 b , 若 $a_i = a+i, b_i = b-i, a_{i+1} = a+(i+1), b_{i+1} = b-(i+1)$, 则存在关系式 $[a_i b_i - a_{i+1} b_{i+1}]$ 为等差数列 ($i=0, 1, 2, 3, \cdots$), 且 $ab > a_i b_i > a_{i+1} b_{i+1}, ab$ 为最大值.

引理 2 k 为奇素数, 如果正整数 Z_0, X_0, Y_0 满足 $X_0^k + Y_0^k = Z_0^k$, 则有 $X_0 + Y_0 - Z_0 \equiv 0 \pmod k$, 或者

$k|(X_0+Y_0-Z_0)$.

证明:参见参考文献[1].

引理 3 $a^m-1=(a-1)(a^{m-1}+a^{m-2}+\cdots+1)$;若 $a\equiv 1(\bmod m^k)$, $m^k|a-1$, 因为 $a\equiv 1(\bmod m)$, 所以 $a^{m-1}+a^{m-2}+\cdots+1\equiv m\equiv 0(\bmod m)$, 也就有 $m|a^{m-1}+a^{m-2}+\cdots+1$, 因此 $m^{k+1}|a^m-1$, 即 $a^m\equiv 1(\bmod m^{k+1})$, $k>0$, $m\geqslant 3$ 的奇素数.

证明:参见参考文献[1].

推论 1 $a^m-1=(a-1)(a^{m-1}+a^{m-2}+\cdots+1)$;若 $a^{m-1}+a^{m-2}+\cdots+1\equiv m\equiv 0(\bmod m)$; $m|a^{m-1}+a^{m-2}+\cdots+1$; 因为 $a^{m-1}+a^{m-2}+\cdots+1\equiv 0(\bmod m)$; 所以 $m|a-1$, 即 $m^2|a^m-1$, $a^m\equiv 1(\bmod m^2)$.

注 1 引理和推论不同,引理有 $m^{k+1}|a^m-1, k\geqslant 1$, 而推论仅有 $m^2|a^m-1, m\geqslant 3$ 的奇素数^[4-8].

引理 4 p 为奇素数, C_{p-1}^k 是 $(a+b)^{p-1}$ 展开式 b_k 的系数, 存在关系式

$$C_{p-1}^k\equiv (-1)^k(\bmod p), \quad k=0,1,2,3,\cdots,p-1.$$

证明:参见参考文献[1].

2.4 实例证明

实例 1 证明 1: 假设 $d_0=1, X_0, Y_0$ 为一偶一奇, 或同为奇数, 引入 $(-1)^e (e=1,2,3,\cdots,k-1)e$ 是 y_0 的幂指数, 则有

$$Z_{02}^k=X_0^{(k-1)}-X_0^{(k-2)}Y_0+X_0^{(k-3)}Y_0^2-\cdots+(-1)^eX_0^{(k-e-1)}y_0^e-\cdots-X_0Y_0^{(k-2)}+Y_0^{(k-1)}.\tag{5}$$

将 $X_0=X_1, Y_0=Y_1$ 代入上式, 并两端同减 1 可得

$$Z_{02}^k-1=X_0^{(k-1)}-X_0^{(k-2)}Y_1+X_0^{(k-3)}Y_1^2-\cdots+(-1)^eX_1^{(k-e-1)}y_1^e-\cdots-X_1Y_1^{(k-2)}+Y_1^{(k-1)}-1.\tag{6}$$

根据引理 2 可知 $k|(X_0+Y_0-Z_0)$, 又有 $Z_{01}|(X_0+Y_0-Z_0)$, 以及因为 $X_0+Y_0=Z_{01}^k, Z_0=Z_{01}-Z_{02}$, 所以有 $\frac{X_0+Y_0-Z_0}{Z_{01}}=Z_{01}^{k-1}-Z_{02}=Z_{01}^{k-1}-1-(Z_{02}-1), k|Z_{01}^{k-1}-1-(Z_{02}-1)$.

因 $(k, Z_{01})=1$, 根据费马定理, $k|Z_{01}^{k-1}-1$, 所以 $k|Z_{02}-1$, 即 $Z_{02}\equiv 1(\bmod k), Z_{02}^k-1=(Z_{02}-1)\times (Z_{02}^{k-1}+Z_{02}^{k-2}+\cdots+1)$.

因为 $(k, Z_{02})=1$, 根据引理 3 有 $k^2|Z_{02}^k-1$, 所以 $Z_{02}^k\equiv 1(\bmod k^2)$, 因此存在 $Z_{02}^k-1=k^2b$. 其中: b 是 Z_{02}^k-1 与 k^2 相除的倍数.

证明 2: 当 $d_0=k$ 时, 有

$$\left. \begin{aligned} Z_0^k&=k^kZ_{01}^kZ_{02}^k, & Z_0&=kZ_{01}Z_{02}, \\ U(x,y)&=X_0+Y_0=k^{k-1}Z_{01}^k, \\ V(x,y)&=kZ_{02}^k=X_0^{(k-1)}-X_0^{(k-2)}Y_0+X_0^{(k-3)}Y_0^2-\cdots-X_0Y_0^{(k-2)}+Y_0^{k-1}. \end{aligned} \right\}\tag{7}$$

假设 $X_1=\frac{X_0+Y_0+1}{2}=\frac{k^{k-1}Z_{01}^k+1}{2}, Y_1=\frac{X_0+Y_0-1}{2}=\frac{k^{k-1}Z_{01}^k-1}{2}$, 将 X_1, Y_1 代入式(2)可得

$$\left. \begin{aligned} Z_0^k&=\left(\frac{k^{k-1}Z_{01}^k+1}{2}\right)^k=\left(\frac{k^{k-1}Z_{01}^k-1}{2}\right)^k, \\ 2^kZ_0^k&=(k^{k-1}Z_{01}^k+1)^k+(k^{k-1}Z_{01}^k-1)^k= \\ &[(k^{k-1}Z_{01}^k)^k+C_k^1(k^{k-1}Z_{01}^k)^{k-1}+C_k^2(k^{k-1}Z_{01}^k)^{k-2}+\cdots+ \\ &C_k^{k-2}(k^{k-1}Z_{01}^k)^2+C_k^{k-1}(k^{k-1}Z_{01}^k)+1]+[(k^{k-1}Z_{01}^k)^k-C_k^1(k^{k-1}Z_{01}^k)^{k-1}+ \\ &C_k^2(k^{k-1}Z_{01}^k)^{k-2}-\cdots-C_k^{k-2}(k^{k-1}Z_{01}^k)^2+C_k^{k-1}(k^{k-1}Z_{01}^k)-1], \\ 2^{k-1}Z_0^k&=(k^{k-1}Z_{01}^k)^k+C_k^2(k^{k-1}Z_{01}^k)^{k-2}+\cdots+C_k^{k-3}(k^{k-1}Z_{01}^k)^3+C_k^{k-1}(k^{k-1}Z_{01}^k). \end{aligned} \right\}\tag{8}$$

上式右端组合数含 1 次 k 因子, 第 1 项含 k 因子高次幂, 且都有 $(k^{k-1}Z_{01}^k)$ 因子, 因此可改写为

$$2^{k-1}Z_0^k=kk^{k-1}Z_{01}^k\left[\frac{(k^{k-1}Z_{01}^k)^{k-1}}{k}+(\frac{C_k^2}{k})(k^{k-1}Z_{01}^k)^{k-3}+\cdots+(\frac{C_k^{k-3}}{k})(k^{k-1}Z_{01}^k)^2+1\right].\tag{9}$$

因为 $Z_0^k=kk^{k-1}Z_{01}^kZ_{02}^k$, 故可改为

$$2^{k-1}Z_{02}^k=\frac{(k^{k-1}Z_{01}^k)^{k-1}}{k}+(\frac{C_k^2}{k})(k^{k-1}Z_{01}^k)^{k-3}+\cdots+(\frac{C_k^{k-3}}{k})(k^{k-1}Z_{01}^k)^2+1.\tag{10}$$

上式两端同减 2^{k-1} 后, 再同除以 2^{k-1} , 可得

$$Z_{02}^k - 1 = \frac{(k^{k-1} Z_{01}^k)^2 \left[\frac{(k^{k-1} Z_{01}^k)^{k-3}}{k} + \left(\frac{C_k^2}{k}\right)(k^{k-1} Z_{01}^k)^{k-5} + \cdots + \left(\frac{C_k^{k-3}}{k}\right) \right] - 2^{k-1} - 1}{2^{k-1}}. \quad (11)$$

费马定理表明: $a^{m-1} \equiv 1 \pmod{m}$; $(a, m) = 1$; 若 $a = b^m$, 则为 $(b^{m-1})m \equiv 1 \pmod{m^2}$

根据对费马定理的解释, 式(11)中 $(2^{k-1} - 1)$ 只能是 $2^{k-1} \equiv 1 \pmod{k^1}$, 即 $k \mid 2^{k-1} - 1$; $2^{k-1} - 1 = kC_2$ (C_2 是 $2^{k-1} - 1$ 除以 k 的倍数), $(k, C_2) = 1$. 则式(11)可变换为

$$Z_{02}^k - 1 = k \frac{(k^{2k-3} Z_{01}^{2k}) \left[\frac{(k^{k-1} Z_{01}^k)^{k-3}}{k} + \left(\frac{C_k^2}{k}\right)(k^{k-1} Z_{01}^k)^{k-5} + \cdots + \left(\frac{C_k^{k-3}}{k}\right) \right] - C_2}{2^{k-1}}. \quad (12)$$

设上式中括号内代数之和为 $\sum C_1$, 则式(12)可改为

$$Z_{02}^k - 1 = k \frac{(k^{2k-3} Z_{01}^{2k}) \sum C_1 - C_2}{2^{k-1}}. \quad (13)$$

式(13)中, 因为 $k \mid (k^{2k-3} Z_{01}^{2k}) \sum C_1$, $(k, C_2) = 1$, 所以 $(k, [(k^{2k-3} Z_{01}^{2k}) \sum C_1 - C_2]) = 1$; 又因 $(k, 2^{k-1}) = 1$, 所以 $\frac{(k^{2k-3} Z_{01}^{2k}) \sum C_1 - C_2}{2^{k-1}}$ 为整数, 设为 a_3 , 即有 $(k, a_3) = 1$. 故式(13)可改为

$$(Z_{02} - 1)(Z_{02}^{k-1} + Z_{02}^{k-2} + \cdots + 1) = ka_3. \quad (14)$$

因为 a_3 为整数, 所以 $k \mid Z_{02}^k - 1$; 又因 k 是奇素数, 根据整除定理, $k \mid Z_{02} - 1$, 或 $k \mid (Z_{02}^{k-1} + Z_{02}^{k-2} + \cdots + 1)$. 若 $k \mid Z_{02} - 1$, 即 $Z_{02} \equiv 1 \pmod{k}$. 根据引理 3 可知, $Z_{02}^{k-1} + Z_{02}^{k-2} + \cdots + 1 \equiv k \equiv 0 \pmod{k}$, 故 $k \mid (Z_{02}^{k-1} + Z_{02}^{k-2} + \cdots + 1)$, 所以 $k^2 \mid Z_{02}^k - 1$. 若 $k \mid Z_{02}^{k-1} + Z_{02}^{k-2} + \cdots + 1$, 即有 $Z_{02}^{k-1} + Z_{02}^{k-2} + \cdots + 1 \equiv k \equiv 0 \pmod{k}$, 故有 $Z_{02} \equiv 1 \pmod{k}$, 所以有 $k^2 \mid Z_{02}^k - 1$; $Z_{02}^k - 1 = k^2 b_3$ (b_3 是 $Z_{02}^k - 1$ 除以 k^2 的倍数). 于是有

$$k^2 b_3 = ka_3, \quad b_3 = a_3/k.$$

由于 $(k, a_3) = 1$, 所以 b_3 为既约分数. 如设 $a_1 = Z_{02} - 1$, $a_2 = Z_{02}^{k-1} + Z_{02}^{k-2} + \cdots + 1$, 则有 $a_1 a_2 = ka_3$. 因为 a_3 是整数, 所以式中 $k \mid a_1 a_2$. 由于 k 是奇素数, 若 a_1, a_2 为整数, 就有 $k \mid a_1$ 或 $k \mid a_2$, 根据引理 3 就有 $k^2 \mid a_1 a_2$, 而实际是 $k^2 \nmid a_1 a_2$, 从而产生矛盾. 因此, 可以证明 a_1, a_2 不为整数, Z_{02} 不为整数而为无理数. 由此可得 $Z_0 = kZ_{01}Z_{02}$, 又因 k, Z_{01} 为整数, Z_{02} 为无理数, 证明 Z_0 为无理数.

实例 2 假设 Z_0 为偶数, X_0, Y_0 为奇数, Z_{01} 为偶数, 则有

$$X_1 = \frac{X_0 + Y_0 + 2}{2} = (k^{k-1} \frac{Z_{01}^k}{2}) + 1, \quad Y_1 = \frac{X_0 + Y_0 - 2}{2} = (k^{k-1} \frac{Z_{01}^k}{2}) - 1. \quad (15)$$

将 X_1, Y_1 代入式(2)可得

$$\begin{aligned} Z_0^k &= \left[\left(k^{k-1} \frac{Z_{01}^k}{2} \right) + 1 \right]^k + \left[\left(k^{k-1} \frac{Z_{01}^k}{2} \right) - 1 \right]^k = \\ &= \left[\left(k^{k-1} \frac{Z_{01}^k}{2} \right)^k + C_k^1 \left(k^{k-1} \frac{Z_{01}^k}{2} \right)^{k-1} + \cdots + C_k^{k-3} \left(k^{k-1} \frac{Z_{01}^k}{2} \right)^3 + \right. \\ &\quad \left. C_k^{k-2} \left(k^{k-1} \frac{Z_{01}^k}{2} \right)^2 + C_k^{k-1} \left(k^{k-1} \frac{Z_{01}^k}{2} \right) + 1 \right] + \left[\left(k^{k-1} \frac{Z_{01}^k}{2} \right)^k + C_k^1 \left(k^{k-1} \frac{Z_{01}^k}{2} \right)^{k-1} + \cdots + \right. \\ &\quad \left. C_k^{k-3} \left(k^{k-1} \frac{Z_{01}^k}{2} \right)^3 + C_k^{k-2} \left(k^{k-1} \frac{Z_{01}^k}{2} \right)^2 + C_k^{k-1} \left(k^{k-1} \frac{Z_{01}^k}{2} \right) - 1 \right]. \end{aligned} \quad (16)$$

上式消项后提取公因数 $2, k, \left(k^{k-1} \frac{Z_{01}^k}{2} \right)$, 加之有 $Z_0^k = k^{k-1} Z_{01}^k k Z_{02}^k$, 可得

$$Z_{02}^k = \left(k^{k-1} \frac{Z_{01}^k}{2} \right)^{k-1} / \left(k + \cdots + \left(\frac{C_k^{k-3}}{k} \right) \left(k^{k-1} \frac{Z_{01}^k}{2} \right)^2 + 1 \right). \quad (17)$$

上式两端同减 1, 右端提取公因数 $(k^{k-1})^2$, 可得

$$Z_{02}^k - 1 = (k^{k-1})^2 \left[(k^{k-1})^{k-3} \left(\frac{Z_{01}^k}{2} \right)^{k-1} / \left(k + \cdots + \left(\frac{C_k^{k-3}}{k} \right) \left(\frac{Z_{01}^k}{2} \right)^2 \right) \right]. \quad (18)$$

设中括号内代数之和为 $\sum C_3$, 则有

$$Z_{02}^k - 1 = (k^{k-1})^2 \sum C_3. \quad (19)$$

上式中, $(k, \left(\frac{C_3^{k-3}}{k}\right)\left(\frac{Z_{01}^k}{2}\right)^2)=1, k \mid \sum C_3 - \left(\frac{C_3^{k-3}}{k}\right)\left(\frac{Z_{01}^k}{2}\right)^2$, 因此有 $(k, \sum C_3)=1$. 因为 $\sum C_3$ 为整数, 所以 $(k^{k-1})^2 \mid Z_{02}^k - 1$. 又因为 $Z_{02}^k - 1 = (Z_{02}^k - 1)(Z_{02}^{k-1} + Z_{02}^{k-2} + \cdots + 1)$; k 为奇素数, 根据整除定理, $(k^{k-1})^2$ 整除 $Z_{02} - 1$, 或 $(k^{k-1})^2 \mid Z_{02}^{k-1} + Z_{02}^{k-2} + \cdots + 1$, 再根据引理 3, $Z_{02}^{k-1} + Z_{02}^{k-2} + \cdots + 1 \equiv k \equiv 0 \pmod k$, 所以 $(k^{k-1})^2 \mid Z_{02}^{k-1} + Z_{02}^{k-2} + \cdots + 1; (k^{k-1})^2 \mid Z_{02} - 1$.

如此根据引理 3 有, $k \mid Z_{02}^{k-1} + Z_{02}^{k-2} + \cdots + 1, k^{2k-1} \mid Z_{02}^k - 1$; 即 $Z_{02}^k \equiv 1 \pmod{k^{k-1}}$. 设 $Z_{02}^k - 1 = k^{2k-1}b_4$ (b_4 是 $Z_{02}^k - 1$ 除以 k^{2k-1} 的倍数), 于是可得

$$k^{2k-1}b_4 = (k^{k-1})^2 \sum C_3, \quad b_4 = \frac{\sum C_3}{k}. \tag{20}$$

因为 $(k, \sum C_3) = 1$, 所以 b_4 为既约分数.

如设 $a_1 = Z_{02} - 1, a_2 = Z_{02}^{k-1} + Z_{02}^{k-2} + \cdots + 1, a_3 = \sum C_3$, 则有

$$a_1a_2 = (k^{k-1})^2a_3. \tag{21}$$

同前面的分析一样, 可以证明 Z_{02} 为无理数, Z_0 为无理数, Z_0 无最小正整数解和正整数解.

3 结论

上面已证明 $X^k + Y^k = Z^k$ 无全正整数解, 若将 n 进行素因数分解, 则有

$$n = 2^l \cdot p_1^{l_1} \cdot p_2^{l_2} \cdot \cdots \cdot p_{l'}^{l'}.$$

式中: $l=0, 1, 2, 3, \cdots, p_{l'}^{l'}$, 为相异奇素因数之积, n 简化为 $n = 2^l p_{l'}^{l'}$, 如此有

$$X^{(2^l p_{l'}^{l'})} + Y^{(2^l p_{l'}^{l'})} = Z^{(2^l p_{l'}^{l'})}.$$

若 $l=1$, 例 $X'^6 + Y'^6 = Z'^6$, 可设 $l=2, p_{l'}^{l'}=3$, 则有 $X^{12} + Y^{12} = Z^{12}$. 若证明其无全正整数解, 就可得 $(X^2)^6 + (Y^2)^6 = (Z^2)^6$ 无全正整数解, 即 $X'^6 + Y'^6 = Z'^6$ 无全正整数解.

因为 $n=4, n=p_{l'}^{l'}$ 时费马大定理成立, 并做如上例中的变换, 所以 $X^n + Y^n = Z^n, n \geq 3$, 不定方程无全正整数解, 即证明费马大定理成立^[9-13].

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《华侨大学学报(自然科学版)》简介

BRIEF INTRODUCTION TO JOURNAL OF HUAQIAO UNIVERSITY (NATURAL SCIENCE)

《华侨大学学报(自然科学版)》(下称《学报》)创刊于1980年,是福建省教育厅主管,华侨大学主办,面向国内外公开发行的自然科学综合性学术理论刊物。

《学报》的办刊宗旨是:坚持四项基本原则,贯彻“百花齐放,百家争鸣”和理论与实践相结合的方针,广泛联系海外华侨和港、澳、台、特区的科技信息,及时反映国内尤其华侨大学等高等学府在理论研究、应用研究和开发研究等方面的科技成果,为发展华侨高等教育和繁荣社会主义科技事业服务。

《学报》以创新性、前瞻性、学术性为办刊特色,主要刊登机械工程及自动化、测控技术与仪器、电气工程、电子工程、计算机技术、应用化学、材料与环境工程、化工与生化工程、土木工程、建筑学、应用数学等基础研究和应用研究方面的学术论文,科技成果的学术总结,新技术、新设计、新产品、新工艺、新材料、新理论的论述,以及国内外科技动态的综合评论等内容。

《学报》既是中文综合性科学技术类核心期刊,又是国内外重要数据库和权威性文摘期刊固定收录的刊源。在历次全国及福建省的科技期刊评比中,《学报》都荣获过大奖。曾获得1995年“全国高等学校自然科学学报系统优秀学报一等奖”,1997年“第二届全国优秀科技期刊奖”,1999年,2008年“全国优秀自然科学学报及教育部优秀科技期刊”,并于2001年入选“中国期刊方阵‘双效期刊’”。

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The Journal has its purpose: adhering to the four cardinal policies, carrying out the principles of the “Flowers Blossom; Schools of Thought Contend” and theory combined with practice, collecting information of science and technology from overseas and those in Hong Kong, Macao, Taiwan and special economic zones and all sides, and in time reflecting the scientific and technological achievements about domestic theoretical research, applied research and development research in our university and others, and serving for development of the overseas Chinese higher education and the socialist prosperity on science and technology.

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