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SUMMATION OF GENERALISED *k*- JACOBSTHAL NUMBERS

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ABSTRACT
In this paper we deliberate closed form of Generalised k-Jacobsthal Numbers.From that we deduce summation formula for -Jacobsthal, k-Jacobsthal Lucas, k-Jacobsthal Derived k-Jacobsthal ,Derived k- Jacobsthal Lucas numbers.

SUBJECT CLASSIFICATIONS: MSC[2010] :11B37,11B39,11B83.

1. INTRODUCTION

There are to many studies in the literature that concern about the special second order such as generalised k-Fibonacci,k-Lucas,k-Jacobsthal etc.In this paper we discuss about Summation of Generalized k-Jacobsthal Numbers. We have discuss it in three cases. . From that We retrieve the Sum formula of k-Jacobsthal, k-Jacobsthal Lucas, Derived k-Jacobsthal, and Derived k-Jacobsthal Lucas

.

NOTATIONS:. $\boldsymbol{J_{k,n}, \hat{j}_{k,n}, D\hat{j}_{k,n}, D\hat{c}_{k,n}}$

2. GENERALISED k −JACOBSTHAL NUMBER:

Let k be any poisitive real Number, $n \in N$, and f, g are scalar valued polynomials with $f^2 + 8g > 0$. Generalization of k-Jacobsthal sequence as a second order linear recurrence sequence $J_{k,n}$ is

$$J_{k,n} = fJ_{k,n-1} + 2gJ_{k,n-2}, n \geq 2.$$

With initial condition $J_{k,0} = a, J_{k-1} = b,$

MAIN RESULTS

SUMMING FORMULA OF GENERALISED k-JACOBSTHAL NUMBER WITH POSITIVE SUBSCRIPTS

Theorem 1.1: Let $x \in C, n \geq 0$

a. If $2gx^2 + fx - 1 \neq 0$

$$\sum_{p=0}^{n} x^p J_{k,p} = \frac{x^{n+2}J_{k,n+2} + x^{n+1}(1 - fx)J_{k,n+1} - xJ_{k,1} + (fx - 1)J_{k,0}}{2gx^2 + fx - 1}$$

b. If $f^2x - 4g^2x^2 + 4gx - 1 \neq 0$

$$\sum_{p=0}^{n} x^p J_{k,2p} = \frac{-x^{n+1}(2gx - 1)J_{k,2n+2} + 2fgx^{n+2}J_{k,2n+1} - fxJ_{k,1} + (f^2x + 2gx - 1)J_{k,0}}{f^2x - 4g^2x^2 + 4gx - 1}$$

c. If $f^2x - 4g^2x^2 + 4g.x - 1 \neq 0$

$$\sum_{p=0}^{n} x^p J_{k,2p+1} = \frac{fx^{n+1}J_{k,2n+2} - 2gx^{n+1}(2gx - 1)J_{k,2n+1} + (2gx - 1)J_{k,1} - 2fgxJ_{k,0}}{f^2x - 4g^2x^2 + 4gx - 1}$$

Proof:

(a)

$$\begin{aligned} J_{k,n} &= fJ_{k,n-1} + 2gJ_{k,n-2} \\ 2gJ_{k,n-2} &= J_{k,n} - fJ_{k,n-1} \\ 2gxJ_{k,1} &= xJ_{k,3} - fJ_{k,2} \\ 2gx^2J_{k,2} &= x^2J_{k,4} - fJ_{k,3} \\ 2gx^{n-1}J_{k,n-1} &= x^{n-1}J_{k,n+1} - fJ_{k,n} \\ 2gx^nJ_{k,n} &= x^nJ_{k,n+2} - fJ_{k,n+1} \end{aligned}$$

Add all the above by side by, we obtain

$$\sum_{p=0}^{n} x^p J_{k,p} = \frac{x^{n+2}J_{k,n+2} + x^{n+1}(1-fx)J_{k,n+1} - xJ_{k,1} + (fx-1)J_{k,0}}{2gx^2 + fx - 1}$$

(b)

$$\begin{aligned} J_{k,n} &= fJ_{k,n-1} + 2gJ_{k,n-2} \\ fJ_{k,n-1} &= J_{k,n} - 2gJ_{k,n-2} \\ fxJ_{k,3} &= xJ_{k,4} - 2gxJ_{k,2} \\ fx^2J_{k,2} &= x^2J_{k,4} - fJ_{k,3} \\ 2gx^{n-1}J_{k,n-1} &= x^{n-1}J_{k,n+1} - fJ_{k,n} \\ 2gx^nJ_{k,n} &= x^nJ_{k,n+2} - fJ_{k,n+1} \end{aligned}$$

Adding all the above equation by side by we get

$$f\left(-J_{k,1} + \sum_{p=0}^{n} x^p J_{k,2p+1}\right) = \left(x^n J_{k,2n+2} - J_{k,2} - x^{-1}J_{k,0} + \sum_{p=0}^{n} x^{p-1} J_{k,2p}\right) - 2g\left(-J_{k,0} + \sum_{p=0}^{n} x^p J_{k,2p}\right)$$

Similarly

$$\begin{aligned} J_{k,n} &= fJ_{k,n-1} + 2gJ_{k,n-2} \\ fxJ_{k,2} &= xJ_{k,3} - 2gxJ_{k,1} \end{aligned}$$

$$\begin{aligned} fx^2J_{k,4} &= x^2J_{k,5} - 2gx^2J_{k,3} \\ fx^3J_{k,6} &= x^3J_{k,7} - 2gx^5J_{k,5} \quad \text{etc ...} \\ fx^{n-1}J_{k,2n-2} &= x^{n-1}J_{k,2n-1} - 2gx^{n-1}J_{k,2n-3} \\ fx^nJ_{k,2n} &= x^nJ_{k,2n+1} - 2gx^nJ_{k,2n-1} \end{aligned}$$

Adding all the above equation by side by we get

$$f(k)\left(-J_{k,0} + \sum_{p=0}^{n} x^p J_{k,2p}\right) = \left(-J_{k,1} + \sum_{p=0}^{n} x^p J_{k,2p+1}\right) - 2g\left(-x^{n+1}J_{k,2p+1} + \sum_{p=0}^{n} x^{p+1} J_{k,2p+1}\right)(3)$$

(2) – (3) we get the result of (b), (c)

Case 1: When $x = 1$ (Substitute $x = 1$ in **Theorem:1** we get the following result.)

Theorem 1.2: For $n \geq 1$

$$a)\ \sum_{p=0}^{n} J_{k,p} = \frac{J_{k,n+2} + (1-f)J_{k,n+1} - J_{k,1} + (f-1)J_{k,0}}{2g + f - 1}$$

$$b)\ \sum_{p=0}^{n} J_{k,2p} = \frac{-(2g-1)J_{k,2n+2} + 2fgJ_{k,2n+1} - fJ_{k,1} + (f^2 + 2g - 1)J_{k,0}}{f^2 - 4g^2 + 4g - 1}$$

$$c)\ \sum_{p=0}^{n} J_{k,2p+1} = \frac{fJ_{k,2n+2} - 2g(2g-1)J_{k,2n+1} + (2g-1)J_{k,1} - 2fgJ_{k,0}}{f^2 - 4g^2 + 4g - 1}$$

Proposition 1.2.1: If $f = k,\ k \in N,$ and $g = 1$ with $J_{k,0} = 0, J_{k,1} = 1$ we get sum formula of $\boldsymbol{k}$ **– Jacobsthal numbers**

$a) \sum_{p=0}^{n} J_{k,p} = \frac{J_{k,n+2} + (1-k)J_{k,n+1} - 1}{k+1}$

$b) \quad \sum_{p=0}^{n} J_{k,2p} = \frac{-J_{k,2n+2} + 2kJ_{k,2n+1} - k}{k^2-1}$

$c) \quad \sum_{p=0}^{n} J_{k,2p+1} = \frac{kJ_{k,2n+2} - 2J_{k,2n+1} + 1}{k^2-1}$

Proposition 1.2.2: If $J_{k,n} = \hat{J}_{k.n}, f = k,\ k \in N,$ and $g = 1$ with $\hat{J}_{k,0} = 2,\ \hat{J}_{k,1} = k$ we get sum formula of ***k* – Jacobsthal Lucas numbers**

$a) \sum_{p=0}^{n} \hat{J}_{k,p} = \frac{\hat{J}_{k,n+2} + (1-k)\hat{J}_{k,n+1} + k - 2}{k+1}$

$b) \quad \sum_{p=0}^{n} \hat{J}_{k,2p} = \frac{-\hat{J}_{k,2n+2} + 2k\hat{J}_{k,2n+1} - k^2}{k^2-1}$

$c) \quad \sum_{p=0}^{n} \hat{J}_{k,2p+1} = \frac{k\hat{J}_{k,2n+2} - 2\hat{J}_{k,2n+1} - 3k}{k^2-1}$

Proposition 1.2.3: If $J_{k,n} = D\hat{J}_{k.n}, f = k,\ k \in N,$ and $g = -1$ with $D\hat{J}_{k,0} = 2,\ D\hat{J}_{k,1} = 1$ we get sum formula of **Derived *k* – Jacobsthal numbers**

$a) \sum_{p=0}^{n} D\hat{J}_{k,p} = \frac{D\hat{J}_{k,n+2} + (1-k)D\hat{J}_{k,n+1} - 1}{k-3}$

$b) \quad \sum_{p=0}^{n} D\hat{J}_{k,2p} = \frac{3D\hat{J}_{k,2n+2} - 2k\hat{J}_{k,2n+1} - k}{k^2-9}$

$c) \quad \sum_{p=0}^{n} D\hat{J}_{k,2p+1} = \frac{kD\hat{J}_{k,2n+2} - 6D\hat{J}_{k,2n+1} - 3}{k^2-9}$

Proposition 1.2.4: Let $J_{k,n} = D\hat{c}_{k.n}, f = k,\ k \in N,$ and $g = -1$ with $D\hat{c}_{k,0} = 2,\ D\hat{c}_{k,1} = k$ we get sum formula of **Derived *k* – Jacobsthal Lucas numbers**

$a) \sum_{p=0}^{n} D\hat{c}_{k,p} = \frac{D\hat{c}_{k,n+2} + (1-k)D\hat{c}_{k,n+1} + k - 2}{k-3}$

$b) \quad \sum_{p=0}^{n} D\hat{c}_{k,2p} = \frac{3D\hat{c}_{k,2n+2} - 2k\hat{c}_{k,2n+1} + k^2 - 6}{k^2-9}$

$c) \quad \sum_{p=0}^{n} D\hat{c}_{k,2p+1} = \frac{kD\hat{c}_{k,2n+2} - 6D\hat{c}_{k,2n+1} + k}{k^2-9}$

Case 2: When $x = -1$ (Substitute $x = -1$ in **Theorem:1** we get the following result.)

Theorem 1.3:

a) If $2g - f - 1 \neq 0$ then

$$\sum_{p=0}^{n} (-1)^p J_{k,p} = \frac{(-1)^n J_{k,n+2} + (-1)^{n+1}(1+f)J_{k,n+1} + J_{k,1} - (f+1)J_{k,0}}{2g - f - 1}$$

b) If $-(f^2) - 4g^2 - 4g - 1 \neq 0$ then

$$\sum_{p=0}^{n} (-1)^p J_{k,2p} = \frac{(-1)^{n+1}(2g+1)J_{k,2n+2} + (-1)^n 2fgJ_{k,2n+1} + fJ_{k,1} - (f^2+2g+1)J_{k,0}}{-(f^2+4g^2+4g+1)}$$

If $-(f^2) - 4g^2 - 4g - 1) \neq 0$ then

$$\sum_{p=0}^{n}(-1)^p J_{k,2p+1} = \frac{(-1)^{n+1} f J_{k,2n+2} + (-1)^{n+1} 2g(2g+1) J_{k,2n+1} - (2g+1) J_{k,1} + 2fg J_{k,0}}{-(f^2+4g^2+4g+1)}$$

Proposition 1.3.1: If $f = k,\ k \in N,$ and $g = 1$ with $J_{k,0} = 0, J_{k,1} = 1$ then we get sum formula of $\boldsymbol{k}$ – **Jacobsthal numbers**

$$a)\ \sum_{p=0}^{n}(-1)^p J_{k,p} = \frac{(-1)^n J_{k,n+2} + (-1)^{n+1}(1+k) J_{k,n+1} + 1}{-k+1}$$

$$b)\ \sum_{p=0}^{n}(-1)^p J_{k,2p} = \frac{(-1)^{n+1} 3 J_{k,2n+2} + (-1)^n 2k J_{k,2n+1} + k}{-(k^2+9)}$$

$$c)\ \sum_{p=0}^{n}(-1)^p J_{k,2p+1} = \frac{(-1)^{n+1} k J_{k,2n+2} + (-1)^{n+1} 6 J_{k,2n+1} - 3}{-(k^2+9)}$$

Proposition 1.3.2: If $J_{k,n} = \hat{J}_{k.n}, f = k,\ k \in N,$ and $g = 1$ with $\hat{J}_{k,0} = 2,\ \hat{J}_{k,1} = k$ we get sum formula of $\boldsymbol{k}$ – **Jacobsthal Lucas numbers**

$$a)\ \sum_{p=0}^{n}(-1)^p \hat{J}_{k,p} = \frac{(-1)^n \hat{J}_{k,n+2} + (-1)^{n+1}(1+k)\hat{J}_{k,n+1} - k - 2}{-k+1}$$

$$b)\ \sum_{p=0}^{n}(-1)^p \hat{J}_{k,2p} = \frac{(-1)^{n+1} + 3\hat{J}_{k,n+2} + (-1)^n 2k\hat{J}_{k,2n+1} - k^2 - 6}{-(k^2+9)}$$

$$c)\ \sum_{p=0}^{n}(-1)^p \hat{J}_{k,2p+1} = \frac{(-1)^{n+1} k\hat{J}_{k,2n+2} + (-1)^{n+1} 6\hat{J}_{k,2n+1} + k}{-(k^2+9)}$$

Proposition 1.3.3: If $J_{k,n} = D\hat{J}_{k.n}, f = k,\ k \in N,$ and $g = -1$ with $D\hat{J}_{k,0} = 0,\ D\hat{J}_{k,1} = 1$ we get sum formula of **Derived** $\boldsymbol{k}$ **– Jacobsthal numbers**

$$a)\ \sum_{p=0}^{n}(-1)^p D\hat{J}_{k,p} = \frac{(-1)^n D\hat{J}_{k,n+2} + (-1)^{n+1}(1+k) D\hat{J}_{k,n+1} + 1}{-k-3}$$

$$b)\ \sum_{p=0}^{n}(-1)^p D\hat{J}_{k,2p} = \frac{(-1)^{n+2} D\hat{J}_{k,2n+2} + (-1)^{n+1} 2k D\hat{J}_{k,2n+1} + k}{-(k^2+1)}$$

$$c)\ \sum_{p=0}^{n}(-1)^p D\hat{J}_{k,2p+1} = \frac{(-1)^{n+1} k D\hat{J}_{k,2n+2} + 2(-1)^{n+1} D\hat{J}_{k,2n+1} + 1}{-(k^2+1)}$$

Proposition 1.3.4: Let $J_{k,n} = D\hat{c}_{k.n}, f = k,\ k \in N,$ and $g = -1$ with $D\hat{c}_{k,0} = 2,\quad D\hat{c}_{k,1} = k$ we get sum formula of **Derived** $\boldsymbol{k}$ **– Jacobsthal Lucas numbers**

$$a)\ \sum_{p=0}^{n}(-1)^p D\hat{c}_{k,p} = \frac{(-1)^n D\hat{c}_{k,n+2} + (-1)^{n+1}(1+k) D\hat{c}_{k,n+1} + 3k + 2}{-(k+3)}$$

$$b)\ \sum_{p=0}^{n}(-1)^p D\hat{c}_{k,2p} = \frac{(-1)^{n+2} D\hat{c}_{k,2n+2} + (-1)^{n+1} 2k\hat{c}_{k,2n+1} - k^2 + 2}{-(k^2+1)}$$

$$c)\ \sum_{p=0}^{n}(-1)^p D\hat{c}_{k,2p+1} = \frac{(-1)^{n+1} k D\hat{c}_{k,2n+2} + (-1)^{n+1} D\hat{c}_{k,2n+1} - 3k}{-(k^2+1)}$$

Case 3: When $x = 1 + i$ (Substitute $x = 1 + i$ in **Theorem:1** we get the following result.)

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Theorem 1.4:

a) If $2g(1+i)^2+f(1+i)-1\neq 0$ then

$$\sum_{p=0}^{n}(1+i)^p\,J_{k,p}=\frac{(1+i)^{n+2}J_{k,n+2}+(1+i)^{n+1}(1-f(1+i))J_{k,n+1}-(1+i)J_{k,1}+(f(1+i)-1)J_{k,0}}{2g(1+i)^2+f(1+i)-1}$$

b) If $f^2(1+i)-4g^2(1+i)^2+4g(1+i)-1)\neq 0$ then

$$\sum_{p=0}^{n}(1+i)^pJ_{k,2p}=\frac{-(1+i)^{n+1}(2g(1+i)-1)J_{k,2n+2}+(1+i)^{n+2}2fgJ_{k,2n+1}-f(1+i)J_{k,1}+((f^2+2g-1)+(f^2+2g)i)J_{k,0}}{f^2(1+i)-4g^2(1+i)^2+4g(1+i)-1}$$

c) If $(f^2(1+i)-4g^2(1+i)^2+4g(1+i)-1)\neq 0$ then

$$\sum_{p=0}^{n}(1+i)^pJ_{k,2p+1}=\frac{(1+i)^{n+1}fJ_{k,2n+2}-2g(1+i)^{n+1}(2g(1+i)-1)J_{k,2n+1}+(2g(1+i)-1)J_{k,1}-2fg(1+i)J_{k,0}}{f^2(1+i)-4g^2(1+i)^2+4g(1+i)-1}$$

Proposition 1.4.1: If $f=k,\ k\in N,$ and $g=1$ with $J_{k,0}=0, J_{k,1}=1$ then we get sum formula of $\boldsymbol{k}$ – **Jacobsthal numbers**

a) If $2(1+i)^2+k(1+i)-1\neq 0$ then

$$\sum_{p=0}^{n}(1+i)^p\,J_{k,p}=\frac{(1+i)^{n+2}J_{k,n+2}+(1+i)^{n+1}(1-k(1+i))J_{k,n+1}-(1+i)}{2(1+i)^2+k(1+i)-1}$$

b) If $(k^2(1+i)-4(1+i)^2+4(1+i)-1)\neq 0$ then

$$\sum_{p=0}^{n}(1+i)^pJ_{k,2p}=\frac{-(1+i)^{n+1}(1+2i)J_{k,2n+2}+(1+i)^{n+2}2kJ_{k,2n+1}-k(1+i)}{k^2(1+i)-4(1+i)^2+4(1+i)-1}$$

c) If $(k^2(1+i)-4(1+i)^2+4(1+i)-1)\neq 0$ then

$$\sum_{p=0}^{n}(1+i)^pJ_{k,2p+1}=\frac{(1+i)^{n+1}kJ_{k,2n+2}-2(1+i)^{n+1}(1+2i)J_{k,2n+1}+(1+2i)}{k^2(1+i)-4(1+i)^2+4(1+i)-1}$$

Proposition 1.4.2: If $J_{k,n}=\hat{J}_{k.n}, f=k,\ k\in N,$ and $g=1$ with $\hat{J}_{k,0}=2,\ \hat{J}_{k,1}=k$ we get sum formula of $\boldsymbol{k}$ – **Jacobsthal Lucas numbers**

a) If $2(1+i)^2+k(1+i)-1\neq 0$ then

$$\sum_{p=0}^{n}(1+i)^p\,\hat{J}_{k,p}=\frac{(1+i)^{n+2}\hat{J}_{k,n+2}+(1+i)^{n+1}(1-k(1+i))\hat{J}_{k,n+1}-(1+i)k+((2k-2)+i2k)}{2(1+i)^2+k(1+i)-1}$$

b) If $(k^2(1+i)-4(1+i)^2+4(1+i)-1)\neq 0$ then

$$\sum_{p=0}^{n}(1+i)^p\hat{J}_{k,2p}=\frac{-(1+i)^{n+1}(1+2i)\hat{J}_{k,2n+2}+(1+i)^{n+2}2k\hat{J}_{k,2n+1}-k^2(1+i)+2(k^2(1+i)+2(1+i)-1)}{k^2(1+i)-4(1+i)^2+4(1+i)-1}$$

c) If $(k^2(1+i)-4(1+i)^2+4(1+i)-1) \neq 0$ then

$$\sum_{p=0}^{n}(1+i)^p \hat{J}_{k,2p+1} = \frac{(1+i)^{n+1}k\hat{J}_{k,2n+2}-2(1+i)^{n+1}(1+2i)\hat{J}_{k,2n+1}+(1+2i)k-4k(1+i)}{k^2(1+i)-4(1+i)^2+4(1+i)-1}$$

Proposition 1.4.3: Let $J_{k,n} = D\hat{J}_{k.n}, f = k,\ k \in N,$ and $g = -1$ with $D\hat{J}_{k,0} = 0,\ D\hat{J}_{k,1} = 1$ we get sum formula of **Derived k – Jacobsthal numbers**

a) If $-2(1+i)^2+k(1+i)-1 \neq 0$ then

$$\sum_{p=0}^{n}(1+i)^p\, D\hat{J}_{k,p} = \frac{(1+i)^{n+2}D\hat{J}_{k,n+2}+(1+i)^{n+1}(1-k(1+i))D\hat{J}_{k,n+1}-(1+i)}{-2(1+i)^2+k(1+i)-1}$$

b) If $(k^2(1+i)-4(1+i)^2+4(1+i)-1) \neq 0$ then

$$\sum_{p=0}^{n}(1+i)^p D\hat{J}_{k,2p} = \frac{-(1+i)^{n+1}(-3-2i)D\hat{J}_{k,2n+2}-(1+i)^{n+2}2kD\hat{J}_{k,2n+1}-k(1+i)}{k^2(1+i)-4(1+i)^2-4(1+i)-1}$$

c) If $(k^2(1+i)-4(1+i)^2-4(1+i)-1) \neq 0$ then

$$\sum_{p=0}^{n}(1+i)^p D\hat{J}_{k,2p+1} = \frac{(1+i)^{n+1}kD\hat{J}_{k,2n+2}+2(1+i)^{n+1}(-3-2i)D\hat{J}_{k,2n+1}-(3+2i)}{k^2(1+i)-4(1+i)^2+4(1+i)-1}$$

Proposition 1.4.4: Let $J_{k,n} = D\hat{c}_{k.n}, f = k,\ k \in N,$ and $g = -1$ with $D\hat{c}_{k,0} = 2,$ $D\hat{c}_{k,1} = k$ we get sum formula of **Derived k – Jacobsthal Lucas numbers**

a) If $-2(1+i)^2+k(1+i)-1 \neq 0$ then

$$\sum_{p=0}^{n}(1+i)^p\, D\hat{c}_{k,p} = \frac{(1+i)^{n+2}D\hat{J}_{k,n+2}+(1+i)^{n+1}(1-k(1+i))D\hat{c}_{k,n+1}-(1+i)k+2(k(1+i)-1)}{-2(1+i)^2+k(1+i)-1}$$

b) If $(k^2(1+i)-4(1+i)^2-4(1+i)-1) \neq 0$ then

$$\sum_{p=0}^{n}(1+i)^p D\hat{c}_{k,2p} = \frac{\begin{array}{c}-(1+i)^{n+1}(-2(1+i)-1)D\hat{c}_{k,2n+2}-(1+i)^{n+2}2kD\hat{c}_{k,2n+1}-k^2(1+i)\\ -2(k^2(1+i)-2(1+i)-1)\end{array}}{k^2(1+i)-4(1+i)^2-4(1+i)-1}$$

c) If $(k^2(1+i)-4(1+i)^2-4(1+i)-1) \neq 0$ then

$$\sum_{p=0}^{n}(1+i)^p D\hat{c}_{k,2p+1}$$
$$= \frac{(1+i)^{n+1}kD\hat{c}_{k,2n+2}+2(1+i)^{n+1}(-2(1+i)-1)D\hat{c}_{k,2n+1}+k(-2(1+i)-1)+4k(1+i)}{k^2(1+i)-4(1+i)^2+4(1+i)-1}$$

CONCLUSION

We discussed Sum formula for Generalised k – Jacobsthal Numbers for three cases. From this we deduced Sum formula for k – Jacobsthal, k - Jacobsthal Lucas, Derived k – Jacobsthal, Derived k - Jacobsthal Lucas.

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